Philosophy of Engineering and Technology

Steen Hyldgaard Christensen
Bernard Delahousse
Christelle Didier
Martin Meganck
Mike Murphy *Editors*

The Engineering-Business Nexus

Symbiosis, Tension and Co-Evolution

Springer

Philosophy of Engineering and Technology

Volume 32

Editor-in-chief
Pieter E. Vermaas, Delft University of Technology, The Netherlands

Editors
Christelle Didier, University of Lille, France
Darryl Cressman, Maastricht University, The Netherlands
Neelke Doorn, Delft University of Technology, The Netherlands
Byron Newberry, Baylor University, U.S.A

Editorial advisory board
Philip Brey, Twente University, The Netherlands
Louis Bucciarelli, Massachusetts Institute of Technology, U.S.A
Michael Davis, Illinois Institute of Technology, U.S.A
Paul Durbin, University of Delaware, U.S.A
Andrew Feenberg, Simon Fraser University, Canada
Luciano Floridi, University of Hertfordshire & University of Oxford, UK
Jun Fudano, Kanazawa Institute of Technology, Japan
Craig Hanks, Texas State University, U.S.A
Sven Ove Hansson, Royal Institute of Technology, Sweden
Vincent F. Hendricks, University of Copenhagen, Denmark & Columbia University, U.S.A
Don Ihde, Stony Brook University, U.S.A
Billy V. Koen, University of Texas, U.S.A
Peter Kroes, Delft University of Technology, The Netherlands
Sylvain Lavelle, ICAM-Polytechnicum, France
Michael Lynch, Cornell University, U.S.A
Anthonie Meijers, Eindhoven University of Technology, The Netherlands
Sir Duncan Michael, Ove Arup Foundation, UK
Carl Mitcham, Colorado School of Mines, U.S.A
Helen Nissenbaum, New York University, U.S.A
Alfred Nordmann, Technische Universität Darmstadt, Germany
Joseph Pitt, Virginia Tech, U.S.A
Ibo van de Poel, Delft University of Technology, The Netherlands
Daniel Sarewitz, Arizona State University, U.S.A
Jon A. Schmidt, Burns & McDonnell, U.S.A
Peter Simons, Trinity College Dublin, Ireland
Jeroen van den Hoven, Delft University of Technology, The Netherlands
John Weckert, Charles Sturt University, Australia

The Philosophy of Engineering and Technology book series provides the multifaceted and rapidly growing discipline of philosophy of technology with a central overarching and integrative platform. Specifically it publishes edited volumes and monographs in: the phenomenology, anthropology and socio-politics of technology and engineering the emergent fields of the ontology and epistemology of artifacts, design, knowledge bases, and instrumentation engineering ethics and the ethics of specific technologies ranging from nuclear technologies to the converging nano-, bio-, information and cognitive technologies written from philosophical and practitioners' perspectives and authored by philosophers and practitioners. The series also welcomes proposals that bring these fields together or advance philosophy of engineering and technology in other integrative ways. Proposals should include: A short synopsis of the work or the introduction chapter. The proposed Table of Contents The CV of the lead author(s). If available: one sample chapter. We aim to make a first decision within 1 month of submission. In case of a positive first decision the work will be provisionally contracted: the final decision about publication will depend upon the result of the anonymous peer review of the complete manuscript. We aim to have the complete work peer-reviewed within 3 months of submission. The series discourages the submission of manuscripts that contain reprints of previous published material and/or manuscripts that are below 150 pages / 75,000 words. For inquiries and submission of proposals authors can contact the editor-in-chief Pieter Vermaas via: p.e.vermaas@tudelft.nl, or contact one of the associate editors.

More information about this series at http://www.springer.com/series/8657

Steen Hyldgaard Christensen
Bernard Delahousse • Christelle Didier
Martin Meganck • Mike Murphy
Editors

The Engineering-Business Nexus

Symbiosis, Tension and Co-Evolution

Foreword by Carl Mitcham

Springer

Editors
Steen Hyldgaard Christensen
Department of Development & Planning
Aalborg University
Aalborg, Denmark

Bernard Delahousse
Département Mesures Physiques
Université de Lille – IUT « A » de Lille
Villeneuve d'Ascq Cedex, France

Christelle Didier
Département des sciences de l'éducation
UFR DECCID
Université de Lille
Villeneuve-d'Ascq, France

Martin Meganck
Faculty of Engineering Technology,
Technologiecampus Gent
KU Leuven
Gent, Belgium

Mike Murphy
Academic Affairs, Digital & Learning
Transformation
Dublin Institute of Technology
Dublin 2, Ireland

ISSN 1879-7202 ISSN 1879-7210 (electronic)
Philosophy of Engineering and Technology
ISBN 978-3-319-99635-6 ISBN 978-3-319-99636-3 (eBook)
https://doi.org/10.1007/978-3-319-99636-3

Library of Congress Control Number: 2018957992

© Springer Nature Switzerland AG 2019
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Engineering and Business: Toward the Fragile Appreciation of a Fraught Relationship

This important volume contributes to a growing literature in engineering studies by advancing critical reflection on relationships between engineering and business. Within the engineering community, engineers often experience conflicts between professional obligations and the demands of corporate employers. Within the business community, engineers are sometimes thought insufficiently sensitive to economic demands—a judgment now being reflected back into engineering school efforts to incorporate economics and entrepreneurship training. But seldom has this tension been subject to the broad, interdisciplinary reflection aimed at in the present volume.

Capitalism—the core of modern business—was coeval with engineering or what some mistakenly insist was just "modern" engineering. Adam Smith's *The Wealth of Nations* (1776) appeared in the same decade as the Smeatonian Society of Civil Engineers (1771), the first such professional association. Although the US National Academy of Engineering has praised engineers for transforming the lifeworld through steam ships, railroads, airplanes, radio, television, and computers (http://www.greatachievements.org), capitalism is credited with being the wealth production machine that has raised billions of people out of poverty. The claim for the primacy of business enterprise—as it has been practiced in the forms of mercantile capitalism (since the early 1500s), industrial capitalism (since the early 1800s), and financial capitalism (since the late 1900s)—has been the central argument of liberal and neoliberal economists.

In the words of Nobel Prize-winning economist Milton Friedman in a 1979 television interview with Phil Donahue that has become a staple of neoliberal websites:

> [T]he only cases in which the masses have escaped from [grinding poverty], the only cases in recorded history, are where they have had capitalism and largely free trade. If you want to know where the masses are worse off, worst off, it's exactly in the kinds of societies that depart from that. So that the record of history is absolutely crystal clear, that there is no alternative way so far discovered of improving the lot of the ordinary people that can hold a candle to the productive activities that are unleashed by the free-enterprise system.

The reality, however, is that capitalism would not have been able to pull off this unprecedented multiplication in human wealth had it not been for engineering. The myth of capitalism alone depends, like all myths, on a careful obscuring of conditionals. Smith's "invisible hand" that leads bakers to provide bread for others would have remained quite limited to those with whom they had personal relationships had the baker not been able to capture, if not enslave, the engineering mentality. Indeed, the superimposition of self-interest over benevolence is a feature as characteristic of engineering as of capitalism. It was the engineering analysis of production into simplified functions that could be used to impose a strict division of labor, as in the famous example of pin manufacture, and the reduction of workers to laborers, together with the enslavement of steam energy to mechanical reproduction, that unleased the forces of exploitation and waste production that have engendered the Anthropocene.

The transformation of capitalism—or the investment of money not to make good products but to make a profit—through the economic captivity of engineering is dramatically illustrated in John Lee Hancock's docudrama *The Founder* (2016) of the McDonald's fast-food chain. The engineering of burger production by the brothers Maurice "Mac" and Richard "Dick" McDonald was done by careful time-and-motion studies along lines pioneered by mechanical engineer Frederick W. Taylor (1856–1915) and industrial engineers Frank (1868–1924) and Lillian Gilbreth (1878–1972). When entrepreneur Ray Kroc (played by Michael Keaton even better than his *Batman*) discovers the original McDonald's system in operation near Pasadena, California, he proposes to franchise it. The McDonald brothers resisted, because of a desire to maintain the quality of their product and a rejection of the ideal of simply increasing profit. For Dick McDonald, high-quality and rapid service were ideals to be protected rather than franchised to increase profits.

Kroc, a money hungry businessman, through repeated pressure eventually persuaded the McDonald brothers to contract with him to open his own McDonald's in Des Plains, Illinois. Over the next few years, by means of underhanded tactics and legal maneuvering, he lowered the quality of the product (by, e.g., replacing real milk shakes with synthetic ones), eventually running the brothers out of business, divorcing his wife, and swaggering onto the stage of business history with a self-promotional (but assisted) autobiography, *Grinding It Out: The Making of McDonald's* (1977). *The Founder* exchange about the milk shakes, however, remains fundamentally revealing:

> Ray: I just found a way to save … hundreds of dollars [with] powdered milk shakes.
>
> Dick: Ray, we have no interest in a milk shake that contains no milk. …
>
> Ray: You don't want to save a bundle.
>
> Dick: Not like that. … It's called a "milk shake," Ray. Real milk, now and forever.
>
> …
>
> Ray: If you don't want to make a profit, that's fine. But don't stop the rest of us [with your] cowering in the face of progress.
>
> Dick: If phony powdered milk shakes is your idea of progress, you have a profound misunderstanding of what McDonald's is about…. You will do as we say. You have a contract….
>
> Ray: You know, contracts are like hearts. They are made to be broken.
>
> …

> Mac: We came up with the … system. Not you, us. What have you ever come up with? Can you name one thing? You can't. And you never have and you never will. Because you are a leach, Ray, you are a professional leach.
>
> Ray: You know what I came up with, Mac, a concept. I came up with the concept of winning. … I want to take the future. I want to win. And you don't get there by being some aw-shucks, nice guy sap. There's no place in business for people like that. Business is war. It's dog eat dog, rat eat rat. If my competitor were drowning, I'd walk over and I'd put a hose right in his mouth. Can you say the same?
>
> Mac: I can't. Nor would I want to.

The irony here is that the original McDonald brothers as businessmen adopted the engineering mentality in order to improve their product, not simply to make money. Money making was a secondary goal. It was Kroc who, as one interested in multiplying the forces of economic growth through the free-enterprise system, captured engineering expertise and turned it to his personal advantage.

Another irony can be found in Kroc's vision of engineering-business nexus as grounded in competition. On Thomas Friedman's "Golden Arches Theory of Conflict Prevention" (from *The Lexis and the Olive Tree*, 1999)—which posits that no two countries with McDonald's in them will go to war—there is a benefit greater than either high-quality hamburgers or increasing profit. Given the challenges of climate change, to which capitalist progress is a dominant contributor, it would be useful to consider ways in which reforms in the engineering-business nexus might enhance explorations of the alternative ideal of degrowth as pioneered in, for example, Romanian American economist Nicholas Georgescu-Roegen's *The Entropy Law and the Economic Process* (1971) and French philosopher Serge Latouche's *Petit traité de la décroissance sereine* (2007; translated as *Farewell to Growth*, 2009).

The articles collected in the present volume, from a broad spectrum of authors and disciplines, cannot help but push readers further into reflection on the multiple ironic relationships between engineering and business. The need for continuing research on these issues is one on which every chapter in the book, separately and even more so together, will stimulate thinking.

International Professor of Philosophy of Technology
Renmin University of China
Beijing

Carl Mitcham

Professor Emeritus
Humanities, Arts, and Social Sciences
Colorado School of Mines
Golden, USA

Preface

In no small part, this volume has been inspired by Robert R. Locke and J. C. Spender's 2011 book *Confronting Managerialism: How the Business Elite and Their Schools Threw Our Lives Out of Balance.* In discussing the difference between management and managerialism and the role of business schools in promoting the latter, they write:

> Managerialism…is a phenomenon associated with membership in a specific group of managers that share specific attributes – a caste. It does not reflect the culture of democratic capitalism with its commitment to collaboration; rather the caste desires to stand apart from society, to become less social and more predatory; to see both markets and businesses as opportunities to plunder, whatever the consequences; to take unforgiving advantage of the errors, misfortunes, and circumstances of others, no matter how they arose…. No aspect of that harm is more pernicious than the role business schools have played in reinforcing the caste's sense of itself and the legitimacy of its predatory instincts done in the name of good management. (Locke and Spender 2011, p. 2)

For many students in engineering and business programs, management roles will be part of their future. Our volume is motivated by the concern that they should be able to critically address such caste-like behavior and values to the extent that they occur in education and practice.

The contributors to this volume thus explore the nexus between engineering and managerialized business. This nexus is complex and multilayered, involving coevolution, tension, and symbiosis. On the one hand, we live in a world that appears to be progressively and relentlessly becoming itself an engineered artifact. More than our roads, buildings, and communications systems are engineered. How we function within our societies is affected and transformed through the activities of engineers and the companies in which they work. In such a world, *thinking about engineering* has become increasingly important and necessary, and yet is challenging and difficult. On the other hand, the majority of the world's population inhabits a world based on an economic model of continuous growth. This economic growth model—an object of critical reflection in itself—provides the historical and current context and the framework in which most engineers work. In this volume, our scope has therefore been expanded to *thinking about engineering and business*, and we locate engineers as actors within the current economic growth ideology.

In our current increasingly engineered society, one ideal of management and controls comes to the fore as the Anthropocene, i.e., the world transformed into an engineered artifact in which human existence is included as well. The human imprint has now become so pervasive and profound that it equals the forces of nature and is thereby turning the Earth into a planetary terra incognita. At the same time, the experience of climate change, which can be associated with the third phase of the Anthropocene, calls for management and control to safeguard planet Earth as a human life supporting system. The Anthropocene therefore raises the question as to how engineering and business together should be considered, given the fact that the current engineering-business *nexus* remains embedded in an economic model of continued growth, whose transformation consequently is called for. It is clear that the transformation deemed necessary to evolve from the current system did not arise as the product of a deliberative choice by individual engineers. This is because it concerns the socioeconomic system as a whole, including our embedded engineering and business practices, rather than a limited set of actors—engineers—within society. The societal and environmental challenges we face are not simple or "tamed" problems, but rather complex or "wicked" problems, and their solution will require interventions at the intersection of technology, business, and society.

With this volume, we want to pick up this thread of reflection on the mutual positioning of engineering, business, and society. Contributors have addressed the connections between engineering and business and the moments of tension between them. They have explored complex relationships between engineering and business from the ideological to the curricular. Professional value systems are identified and compared. Ways of seeing the world through the lens of these value systems are explored, with a focus on how they are embedded in engineering and business cultures. Finally, contributors have explored and posited movements to reshape, reform, and even reject the engineering-business nexus and how these are appearing in engineering education.

The present volume continues efforts in previous publications to explore ways in which scholars from the humanities, social sciences, and engineering can contribute to engineering education. This is approached partly through an appreciation of the multiple contexts within which engineers work and partly through appreciation of the challenges with which engineers, engineering institutions, and engineering education are currently confronted. We provide additional context by examining a number of engineering ideologies and looking at historical case studies that shed light on current realities. How engineers function within the workplace and the practices of those engineers are described in order to extract key attributes of workplace engineers and the tensions they face. We close by examining how the engineering-business nexus is configured within the higher education system. Throughout, we have tried to confront and challenge real developments past and present.

While systems at rest tend to remain at rest, external pressures on engineering education systems have created a movement to innovate engineering programs. Among other responses, the development of hybrid engineering programs has proliferated. In part, this is to meet corporate demands, to respond to national priorities, and thus to provide a more relevant education to engineering students. The novelty of this volume is that our approach to the engineering-business nexus does not come from a narrow curriculum development need, but rather through examining the broader transformations affecting engineering practice, and therefore, how the splintering and hybridization occurring at a micro (i.e., course or curricular) level is caused by changes in business practice at the macro level.

Contributions to this volume stem from networks that were established in previous collaborative projects, beginning with a 2003 precursor, *Profession, Culture, and Communication: An Interdisciplinary Challenge to Business and Engineering*, edited by Steen Hyldgaard Christensen and Bernard Delahousse and published by the Institute of Business Administration and Technology Press, Herning. This initial collaboration was continued through a series of book projects initiated and coordinated by Steen Hyldgaard Christensen and new partners at the international level, including especially Carl Mitcham, Colorado School of Mines and Renmin University of China, who acted as a key node in the network. Other publications in the series include:

- Steen Hyldgaard Christensen, Bernard Delahousse, Martin Meganck (eds.) (2007), *Philosophy in Engineering*, Academica, Aarhus
- Steen Hyldgaard Christensen, Bernard Delahousse, Martin Meganck (eds.) (2009) *Engineering in Context*, Academica, Aarhus
- Steen Hyldgaard Christensen, Carl Mitcham, Li Bocong, and Yanming An (eds.) (2012), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives*, Springer Science+Business Media B.V.
- Steen Hyldgaard Christensen, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, Byron Newberry (eds.) (2015), *International Perspectives on Engineering Education; Engineering Education and Practice in Context, Volume I*, Springer Science+Business Media B.V.
- Steen Hyldgaard Christensen, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, Byron Newberry (eds.) (2015), *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context. Volume II,* Springer Science+Business Media B.V.

The volume is addressed to both teachers and students in engineering and business disciplines as well as practitioners and educational policy-makers, on political and institutional levels. It is the result of a long writing and editorial process. Hopefully readers will find it worthwhile, particularly as it aims at inspiring us all to do more thinking and rethinking about the engineering-business nexus and to launch further research in this important field.

Aalborg, Denmark — Steen Hyldgaard Christensen
Villeneuve d'Ascq Cedex, France — Bernard Delahousse
Villeneuve-d'Ascq, France — Christelle Didier
Gent, Belgium — Martin Meganck
Dublin 2, Ireland — Mike Murphy
20 September 2016

Contents

Chapter 1
General Introduction: The Engineering-Business Nexus: Nature, History, Contexts, Tensions

Steen Hyldgaard Christensen, Bernard Delahousse, Christelle Didier, Martin Meganck, and Mike Murphy

> The vested rights of absentee ownership are still embedded in the sentiments of the underlying population, and still continue to be the Palladium of the Republic; and the assertion is still quite safe that anything like a Soviet of technicians is not a present menace to the vested interests in America. (Veblen 1921, p. 128)

> The engineer is both a scientist and a business man. (Layton 1971, p. 1)

> While the systematic monopolization of scientific knowledge by the professionals increased the autonomy of scientists, however, it had the opposite effect upon engineers, tying them to the large corporation. (Noble 1977, p. 43)

Questions about the nature, history and context of the engineering-business nexus related to specific times and countries are not new, as evidenced by the quotations given above from three American classics: Thorstein Veblen's *The Engineers and*

S. H. Christensen (✉)
Department of Development & Planning, Aalborg University, Aalborg, Denmark
e-mail: steenhc@plan.aau.dk

B. Delahousse
Département Mesures Physiques, Université de Lille – IUT « A » de Lille, Villeneuve d'Ascq Cedex, France

C. Didier
Département des sciences de l'éducation UFR DECCID, Université de Lille, Villeneuve-d'Ascq, France
e-mail: christelle.didier@univ-lille.fr

M. Meganck
Faculty of Engineering Technology, Technologiecampus Gent, KU Leuven, Gent, Belgium
e-mail: martin.meganck@kuleuven.be

M. Murphy
Academic Affairs, Digital & Learning Transformation, Dublin Institute of Technology, Dublin 2, Ireland
e-mail: mike.murphy@dit.ie

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_1

the Price System (1921), Edwin Layton's *The Revolt of Engineers* (1971), and David Noble's *America by Design* (1977). What these classics have in common is that they all set out to examine the consequences related to a decisive moment in the history of business and engineering in the United States, namely the emergence of the multidivisional business corporation – a new institutional entity constituting a main feature of corporate capitalism or what Harry Braverman (1974) calls monopoly capital. Each in its own way has shown how the professional ideals and aspirations embraced by many American engineers during the Progressive Era, from the 1890s to the 1920s, were in marked tension with business imperatives and bureaucratic loyalties. Nevertheless the work of both Edwin Layton and David Noble helped to contextualize the professionalization of American engineers. They also showed how prevailing engineering values and attitudes were frequently interchangeable with a business ethos inculcated through dominant pathways in engineering education and career trajectories. At a more general level the conflicting values and commitments of professionals and managers have been substantiated in Joseph A. Realin's 1985 book *The Clash of Cultures: Managers and Professionals* in which he proposes how professionals should be managed to avoid a clash of cultures.

The engineering-business nexus has also been a persistent subtheme in engineering ethics. In their 2000 book *Introduction to Engineering Ethics* Mike W. Martin and Roland Schinzinger write:

> From its inception as a profession, as distinct from a craft, much engineering has been embedded in corporations. That is due to the nature of engineering, both in its goal of producing economical and safe products for the marketplace and in its usual complexity of large projects that requires that many individuals work together. (Martin and Schinzinger 2000, p. 19)

Though some engineers also work within government entities, or for non-profits, such as humanitarian organizations, the bulk of engineering activity occurs in the service of business and industry. In highly technological businesses, it is not uncommon for engineers to take on business management functions and often rise into the executive ranks. So, while engineering and business are generally studied as distinct entities, they are deeply symbiotic. Further, engineering and business are both quite diverse. Engineering has a wide array of disciplines, and a wide array of job functions within each discipline. And the companies that engineers work for provide a panoply of products and services, range in scale from small consultancies to giant multinationals, and vary across a spectrum of political and cultural environments. Thus there is a complex business-engineering ecology that defies any simple characterization of the engineering-business relationship. The engineering-business relationship is also complicated by tension between the two – most often a tension between the demands of the marketplace and the ideals of the profession.

Examination of the social context in which the large corporation arose, and how this new entity was regarded by society, shows that the birth of the business corporation represented more than a simple development and implementation of new technologies and adaptation to new market conditions. In itself the multidivisional business corporation was an important innovation, because it professionalized the big company and set its dominant structure. In this way the business corporation became the template for "managerialism". John Micklethwait and Adrian Wooldridge in their 2003 book *The Company: A Short History of a Revolutionary Idea* put it this way: "If the archetypical figure of the Gilded Age was the robber baron, his successor was the professional manager – a more tedious character, perhaps, but one who turned out to be surprisingly controversial" (ibid., p. 103). Ultimately, as Joel Bakan unveils in his 2004 book *The Corporation. The Pathological Pursuit of Profit and Power,* the large business corporation was also linked to emerging social, intellectual and cultural conditions, or more precisely to the disruption of an entire social order. As noted by Braverman (1974, p. 260) prior to 1850 very few American firms needed the services of a full-time administrator. Neither did they require a clearly defined administrative structure as industrial enterprises were very small. Administration in such small businesses was usually a family affair. Its basic economic, administrative, operational, and entrepreneurial activities could normally be handled by two or three men responsible for the destiny of the enterprise.

As the business corporation came to replace the small traditional family firm Alfred D. Chandler in his 1977 classic *The Visible Hand: The Managerial Revolution in American Business* noted that in many sectors of the economy,

> The visible hand of management replaced what Adam Smith referred to as the invisible hand of market forces. The market remained the generator of demands for goods and services, but modern business enterprise took over the functions of coordinating flows of goods through existing processes of production and distribution, and of allocating funds and personnel for future production and distribution. As modern business enterprise acquired functions hitherto carried out by the market, it became the most powerful institution in the American economy and its managers the most influential decision makers. (Chandler 1977, p. 1)

Chandler extends and deepens insights that can be found as well in a 1932 analysis by Adolf A. Berle and Gardiner C. Means, *The Modern Corporation and Private Property,* which picked up on the significance of the divorce of ownership from the control of the business corporation, as did Veblen's 1923 *Absentee Ownership and Business Enterprise in Recent Times: The Case of America*.

From the second half of the nineteenth century, however, it was not clear whether graduates from engineering schools or graduates from emerging business schools would provide leadership in society, industry, and emergent large business corporations, and whether they should pursue higher aims of service beyond material rewards and profit. With respect to the emergence of the American business school the taken-for-granted assumption that an enormous cadre of salaried managers should manage the business corporation on behalf of absentee owners was a historical contingency. The business school was established for a growing occupation in search of legitimacy. In Rakesh Khurana's account (Khurana 2007) the emergence of the American business school in 1881 was founded on the promise of turning management into a profession for higher aims.

Consequently, at the beginning, the rhetoric of both engineers and managers implied aspirations of providing professional leadership for higher aims. However, these groups emerged as a response to social needs related to their occupational practice, and the discussion about higher aims came along later. Although at the level of early practice the question of doing good – and giving oneself some rules – was always an issue for some people, the formalization of education and the emergence of new groups – the “professionals”, or the “graduates” – was the result of a whole process. First came the needs from the practice of their trade, secondly came the need for formal education, and finally the collective discussion about the other goals such as higher aims. Today, however, and perhaps more than ever before, business leaders and practicing engineers face a complex interdependence. This interdependence arguably affects all participants in the global economy, and in our increasingly interconnected world it is becoming ever more obvious that actions providing immediate advantage to some cannot be counted on to benefit all. A glaring example of such actions that provide advantage to a single group to the detriment of other stakeholders is the way business managers are incentivized:

> The tactic of “incentivizing” managers with stock options, for example, followed from a market logic – inculcated in directors and managers alike by business schools beginning in the 1970s – that assumes that managers are both purely self-interested and motivated only by the prospects of lavish material rewards. By demoting managers from professional stewards of the corporations resources to hired hands bound only by contractual requirements and relationships, business schools thus helped create the conditions and standards of behavior through which the market-based mechanism of stock options was turned into instrument of defrauding investors, jeopardizing the livelihoods of employees, and undermining public trust in managers and corporations. (Khurana 2007, p. 375)

These new times raise questions about business and engineering practices, the meaning of leadership and expertise, and, ultimately, the very purpose of business and engineering. For engineers this is all the more relevant as we live in a progressively engineered world, which raises troubling questions regarding the meaning of life and the goals of societies in this kind of world.

In light of this background, the purpose of this book is to explore the engineering business ecology in order to increase our understanding of its nuances. This includes understanding the common ground between business and engineering, as well as differences between them. Our aim is to explore perceived benefits and challenges, compatibilities and tensions, and agreements and misunderstandings within the engineering/business relationship, and consequent implications for society. In the process, we also want to highlight the importance of the engineering/business relationship in the education of engineers.

The present volume therefore interrogates multilayered relationships between engineering and business on a broad international canvas with an eye to the social transformation of business schools and the unfulfilled promise of management as a profession (Khurana 2007). Key overlapping questions that inform the volume are:

- What kinds of conflict arise for engineers in their attempt to straddle both professional and organizational commitments?

- How should professionals be managed to avoid a clash of managerial and professional cultures?
- How do engineers create value in firms and corporations?
- What kinds of tension exist between higher education and industry?
- What kinds of tension does the neoliberal entrepreneurial university pose for management, faculty, students, society, and industry?
- Should engineering graduates be ready for work, and can they possibly be?
- What kinds of business issues are reflected in engineering education curricula, and for what purpose?
- Is there a limit to the degree of business hybridization in engineering degree programs, and if so, what would be the criterion for its definition?
- Is there a place in engineering education curricula for reflective critique of assumptions related to business and economic thinking?

As regards the last bullet question, concerns have been voiced over the narrowness of business curricula and the lack of reflective critique resulting in the failure of business educators to challenge students to question assumptions, to think creatively, and to understand the place of business in larger institutional contexts. Prominent examples of scholarly work that point to the need to address this situation are Rakesh Khurana's 2007 book *From Higher Aims to Hired Hands: The Social Transformation of American Business Schools and the Unfulfilled Promise of Managements as a Profession,* Anne Colby, Thomas Ehrlich, William M. Sullivan and Jonathan R. Dolle's 2011 book *Rethinking Undergraduate Business Education: Liberal Learning for the Profession,* and Robert R. Locke and J.-C. Spender's 2011 book *Confronting Managerialism: How the Business Elite and their Schools Threw our Lives out of Balance.* In spite of dispersed initiatives the situation seems to be quite similar in engineering education curricula. All the more so is this the case since STEM fields play a crucial role in the neoliberal entrepreneurial university and managerialism and administrative bloat have been flourishing in this new corporatized entity.

In addressing the above-mentioned questions the present volume collects 21 original contributions grouped into four parts. Part I concerns engineering and business value systems, and Part II engineering and business ideologies past and present. Part III has its focus on the practices of business and engineering. Finally the focus of Part IV is on engineering and business education.

1.1 Part I: Engineering and Business Value Systems

The five chapters in the first part of the present volume examine the relationship between business and engineering through the values and ideologies as conveyed by scholars of these two occupations in various geographical areas in North America and Europe respectively and who normally speak different native languages. For the sake of precision: American English is the native language of two American scholars, British English the native language of an Irish scholar, and French the native language of a Quebecois and a Frenchwoman. This part of the volume thus evokes the values of two occupations morally characterized in various ways according to the cultural moorings and industrial histories of each of the universes traversed in this first part. The various perspectives also depend on the chosen theoretical disciplines and frameworks, whether it is philosophy, ethics, or social science.

Through contrasting North America with Europe, the first part of the book highlights the influence of political and social contexts on the production of ideas and categories of analysis. In particular the boundaries between two occupational worlds, namely that of business people and that of engineers, are highlighted. Readers of Chaps. 2 and 3 will find that the demarcation approach that comes into view in these chapters is echoed in the Canadian Iron Ring ceremony as presented in Chap. 8. Moreover the critical perspective proposed in Chap. 6 which traces the construction of several professional models to the Middle Ages, will find some resonance, though less distant than the Middle Ages, in some of the chapters in Part II, especially in Chap. 7. In addition, Chap. 5 shares with Chap. 16 an approach focused on actors at work and with Chap. 13 a diachronic approach to careers, but above all a more interactionist perspective on professions and a more fluid understanding of occupational boundaries. Readers will find that the captivity argument advanced in Chap. 4 is reflected in Chap. 9 with respect to the captivity of Chinese entrepreneurs and engineers under the socialist planned economy. Furthermore readers of Chap. 4 may delve deeper into the discussion on the need to develop the critical thinking skills of engineers by considering Chaps. 17 and 18 which both address the broader outcomes of engineering education. In the following we present each chapter in Part I in its own right.

U.S. philosopher of the professions, Michael Davis in Chap. 2 analyzes the evolution of the relationship between engineering and business, two human activities he clearly distinguishes by means of the nature and moral obligations that flow from them. According to the functionalist framework he adopts – matching that of sociologist Rakesh Khurana – business management should not be considered as a profession in contrast to engineering which should be. Consistent with the author's definition of a profession as "a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a moral ideal in a morally permissible way beyond what law, market, morality and public openness would otherwise require" (Davis 2009, p. 217), business management does not qualify as a profession whereas engineering clearly fulfills the criteria of being a full blown profession. Davis proposes that MBA students should study the professions in terms of their culture, values, and standards. He also defends the idea that business schools should not so much prepare their students to become "leaders" who should "manage professionals". Rather they should prepare students to know how to "manage with professionals" like engineers and other professionals. The author's view might be more meaningful for readers for whom "profession" is a stabilized legal and/or social institution and status. Still, however, an evident need for business managers and engineers – trained in different types of institution in most countries – to be socialized to understand each other's occupation comes into view as an issue that goes beyond any cultural and geographical specificity.

In Chap. 3, Quebec ethics philosopher Luc Bégin and his colleagues analyze the tensions encountered by engineers between the ideals of their profession and the expectations of their employers. The founder in 2004, and active director of the Laval University Applied Ethics Institute (IDEA, *Institut D'Ethique Appliquée*), Bégin has regularly served as an ethics expert for the Quebec Government and for several professional orders, such as the *Ordre des ingénieurs du Québec*. The research question posed in this chapter relates to the same geographical context as Davis, North America. Although they do not belong to the same culture, Canadians – even in French-speaking Québec – share many values with Americans. If contrasted with other continents' approaches, there are also similarities in the ways Canadian and American scholars deal with occupational ethics. But there are also differences, especially for engineers. In Quebec the title of engineer is socially considered as a "privilege", and engineers are organized – as in the rest of Canada – as a "regulated profession". Moreover, and importantly the first and foremost legal obligation of the Order which controls them is to protect the public. In the context of the time and these entitlements, Bégin and his colleagues have observed an erosion of the professional ideals, which led them to focus their present study on the tension encountered by the engineers who work for very large public and private organizations. In order to counteract this erosion, they propose (a) that the state imposes an obligation on companies that they should guarantee a right for engineers to respect and fulfill their professional moral duties, (b) to develop a better mutual understanding of the respective values of the engineers and their employers, as well as (c) to ensure a better legal protection for whistleblowers. Although their contexts differ, Davis and Bégin share the view that engineers and business managers (Davis) or their employers (Bégin et al.) need a better understanding of each other's value framework.

Irish scholar Edward Conlon, in Chap. 4, takes a Marxist approach to engineering ethics. Despite the fact that in this theoretical approach and geographical context there are occupational groups socially defined as "professions" – and sometimes legally defined as regulated/chartered professions – the notion does not match Davis' definition. Moreover in the Irish social context the engineering title is not regarded as a privilege. In point of fact the notion of profession does not need to be defined here because Conlon does not base his research on the nature or status of engineering as a group whether its denomination is occupation or profession. He studies the concrete engineers' decisions and actions in their work context using the sociological distinction between structure and agency. Rather than discussing the relationships between engineers and their managers seen as interdependent equals or the engineers' dual obligations toward their employers and their order, the author puts forward the concept of the captivity of engineering by the capitalist machine to develop his points regarding critical issues in engineering ethics. From this perspective, the efforts of engineers to address the critical issues of safety and sustainability are seen as prevented or hindered by structural constraints that weigh heavily on their professional practice. By mobilizing Margaret Archer's theory of critical realism which is neither determinist nor relativist, the author proposes to develop an ethical training strategy capable of contributing to the emancipation of engineers by strengthening their capacity to analyze the context in terms of the structure of their practice as a way to develop new means of action.

Glen Miller, U.S. philosopher, analyzes in Chap. 5 the ethics of engineering from an individual and Western perspective which is both realistic and sensitive to the weight of contingencies. By way of addressing the business-engineering nexus more implicitly, the approach differs considerably from the previous ones. In a micro-subjective approach the author focuses on the way individual engineers might "navigate" the engineering-business space in terms of how they deal with the ethical issues within their actual work and how they make career choices. He also questions the relationship between professional ethics and ethics taken in a broader sense. According to the author, the ethics codes produced by engineering organizations "in some countries" or by program accreditation bodies like ABET in the U.S. and EUR-ACE in Europe are good resources for an ethical career at the beginning of a professional trajectory, thereby enabling engineers to become rule-following employees. However, he also notes that they are insufficient beyond that. Miller proposes to go beyond the preventive/prohibitive approach of the codes by founding his approach on W. D. Ross' ethics of obligations, which he considers compatible with the moral stipulations of ABET and EUR-ACE. According to Miller, the development of individual dispositions to virtue can accompany, better than codes, the ability of engineers to navigate the engineering-business space over a life-long career path.

Finally in Chap. 6, French sociologist Christelle Didier proposes to stage the debates on professional values differently, by enlarging the perspective to a broader historical context without taking *the higher aims* of the profession for granted in the way of scholars such as Davis and Khurana associated with the North American tradition. She revisits the medieval European context, with its Catholic bodies and Saxon brotherhoods, as well as the Puritan conceptions of vocations which served as a framework for many academic studies of the professions and their ethics. Many of these studies have been carried out by British scholars but in the main by scholars from North America. In fact the concept of "profession" – without the adjective "regulated" – as distinct from the notion of "occupation", whatever its definition, developed in the English-speaking world, does not have an exact equivalent in the majority of other languages, such as the author's native French language as well as in Japanese to mention two recognizable examples, because it belongs to a certain type of social stratification. The author proposes to clear up a few misunderstandings in this respect as well as misunderstandings related to cultural, linguistic and theoretical aspects that accompany most university discussions on the ethics of engineering and business, and the role the concept of profession plays in these endeavors. The author emphasizes the need to question some of the basic assumptions, if the aim is intercultural exchanges, to maintain a fruitful debate.

1.2 Part II: Engineering and Business Ideologies Past and Present

The six chapters in the second part offer historical reflections on engineering and business ideologies past and present as well as reflections on reform efforts in higher education that have been informed by the dominant economic discourse of neoliberalism originating in the 1970s and the associated discourses of "new public management" from the 1980s. Geographically the chapters span past and present developments in the United States, Canada, the United Kingdom, Ireland, and China. However as Chap. 10 is focused on how the key composite engineering competence "acting as an engineer in an organization" can best be learned, it could just as well have been located in Part IV as a complement to Chap. 22 as both these chapters relate to bullet 6 under the key overlapping questions mentioned earlier. Yet the Chaps. 10, 11, and 12 may be read as a triptych as their common theme, in spite of considerable variation in subthemes, is the expansion of higher education systems in the United Kingdom, the United States, and Ireland from the post-WWII period to the present. Readers of Chaps. 7 and 8 should also consider Chap. 2 in which Veblen's 1921 book *The Engineers and the Price System* is given a lengthy treatment from a historical perspective. Here the author points out that Veblen's use of the notion of engineer, industrialist, and technologist is somewhat arbitrary but that he did identify important issues of a perennial nature between engineers and business management. These chapters have Veblen either wholly or partially in common, but they differ considerably in approach; yet some common conclusions can be taken from them. Finally using the story of McDonald's as a case in point and without making explicit reference to Veblen, the Foreword nevertheless provides an exemplification of his engineering-business dichotomy.

Drawing on Veblen's early, mid-career, and later work on "technicians", in the opening Chap. 7 the Danish and French academics Steen Hyldgaard Christensen and Bernard Delahousse respectively set out to reinterpret Veblen's 1921 book *The Engineers and the Price System* as regards the theoretical status of his projected *Soviet of Technicians*. Their reinterpretation is undertaken in light of his deconstruction of the engineering-business nexus which reflects Veblen's epistemological, ontological, and axiological commitments. Moreover their reinterpretation is founded on two methodical premises reflected in the structure of the chapter: (1) it should be based on a close-reading of the text, and (2) it should locate the text both within the theoretical context of Veblen's theory of corporate capitalism and in his Darwin-informed evolutionary theory. They advance from the recognition that Veblen explored the cultural contradictions of capitalism in terms of a contradiction between industry and business, whereby he enabled an understanding of why factories rarely worked at full capacity and in addition pointed to the business corporation as a key development in finance capitalism. They show that from an anthropological perspective Veblen traced this contradiction to the residual habits of primitive societies in terms of two clusters of instincts – group-regarding versus self-regarding instincts – and thereby identified the persistent presence of residual habits of primitive societies in modern American life. By juxtaposing engineers to the "pecuniary class" Veblen, as part of his research program on social movements, aimed to explore a possible candidate movement such as the one led by progressive engineers with the potential to delegitimize the prevailing business ideology for a final socialist overturn. They emphasize that during the course of their study they have observed a tendency among engineering education researchers and historiographers of engineering to reduce the complexity of Veblen's thought to a number of his provocative statements. This means that the theoretical system behind such statements has been neglected, with the result that a more balanced assessment of the critical potential of Veblen's theoretical system, and his key insights regarding the inherent contradictions of capitalism, have been lacking. They conclude by establishing a trial balance of strengths and weaknesses in Veblen's work on technicians.

In Chap. 8 Canadian historiographer of science and technology, Janis Langins, picks up on the historiography of engineering and the conflicting ideologies of engineering and business in the United States during the Progressive Era and their reflection in a later industrializing Canada. He notes that in both countries the influence of modern business as well as academic engineering education became increasingly important and central to the ethos of engineers. His narrative is focused on the Canadian "Iron Ring" ceremony instituted by Herbert E. T. Haultain (1869–1961), a Toronto professor of mining engineering. He clarifies form and content of the ceremonial ritual created by Rudyard Kipling to initiate engineering graduates into their profession. The ritual commemorates an age of masculine engineering heroism, self-denial, and sense of duty in which great engineering works were not yet so common as to be taken for granted by the general populace. Kipling's poem *The Sons of Martha* served as the core of the ceremony. The author makes it clear that Kipling employed the analogy between Martha and engineers in the biblical allegory of Mary and Martha (Luke 10:38–42) and that he portrays engineers as the people who make it possible for the rest of society to "choose the better Part". In contextualizing the poem and the response it elicited in 1919 in the form of a new poem titled *The Sons of Mary* advocating the values of a distinctly pro-business ideology, he clarifies the changing relationship between engineering and business ideologies and traces the way engineering developed in the United States and Canada. In so doing he relates the two poems to themes in Veblen's work and seeks to identify the contradictions in both of these conflicting ideologies. He concludes that both these ideologies contributed to forming the uneasy nexus between business and engineering that continued to evolve during the twentieth century.

The entrepreneur as a social character as well as a class of people smacks too much of unfettered private initiative and business not to constitute a precariat when this character emerges in a socialist plan economy. The narrative of Chap. 9 by the Chinese philosophers of engineering and technology, Wang Nan and Li Bocong, addresses this situation in China during the period of "opening up" from 1978 to 1992 under the leadership of Deng Xiaoping. By first exploring various meanings of the notion of entrepreneur they go on to discuss historical periodization. As the "opening up" period constitutes a whole in itself following European antecedents in historical periodization, they argue that it would be meaningful to term it "the

Long 1980s". They articulate that the outcome of Deng's leadership was a nation that underwent huge social transformations, but remained subject to the rule of the communist party, even though it lost its strong ideological moorings. Having defined the engineering community they explore the consequences for the engineering community of Mao Zedong's (1893–1976) harsh leadership from the 1950s to the 1970s, whereby an anomaly in the engineering community was created as entrepreneurs were lacking and engineers like other intellectuals were restricted. If entrepreneurs had disappeared under Mao they reemerged under Deng, and engineers who had been restricted in their work evolved into a special kind of engineers, Sunday Engineers. They finally explore a number of cases in which the extra money Sunday Engineers were able to earn by working on Sundays, helping factories in the countryside to become more effective, became a subject of ideological controversy and law suit for bribery before official ideological acclaim was in place.

The English engineering educator and researcher John Heywood, resorting to the history of higher technical education in the United Kingdom, starts in Chap. 10 from the general observation that there is a perennial conflict between education and industry in terms of the different perceptions educators and industrialists have regarding the purposes of higher education. He makes it clear that presently there is a pressure on the higher education sector that it should prepare new graduates immediately for work in industry. He sets off from the recognition that educating and training graduates to act confidently as engineers or technologists in an organization solely through academic study is impossible. In support he points to a growing body of literature providing evidence to the fact that the key engineering competence "acting as an engineer in an organization" can only be learned on site. He then goes on to examine an exemplary case regarding the education and training of engineers and technologists in England and Wales in the 1950s and 1960s, and thereby provides an understanding of how the new post-WWII system of higher technological education in the United Kingdom came about and how its expansion was projected to respond to the need for technical manpower obeying the *gold standard* of academic degrees in technical diploma (dip. tech). During this period of time the combination of academic study and industrial work – the sandwich principle – came close to forming an ideal national curriculum for higher technological education and training, but in the end it did not become as successful as it could have been due to the fact that the responsibility of industry and academia was not appropriately shared.

Taking a job creation perspective, the Irish and North American academics, Mike Murphy and Michael Dyrenfurth respectively, in Chap. 11 examine the role of neoliberal entrepreneurial universities as job creators and as engines of economic growth in the increasingly knowledge-led global economy. They first look into how the role of the university has expanded from traditional first and second mission activities, in terms of teaching and research, to encompass third mission activities that include industry engagement and how this engagement supports job creation and economic development. Next they examine how new jobs are created within a geographic region or country, and the role the university can play in support of this. Finally, they examine the role of government and policy related to sustainable job creation. They start from the premise that if the regional or national goal is job growth, then the focus should be on how largest job growth occurs. They argue that maximum job creation is best achieved through the attraction of large companies, support for growth of small and medium-sized companies, and the nurturing of start-up companies. In Ireland, the government has taken the approach of consistently attracting foreign direct investment, investing heavily in higher education, and providing a favourable business environment, including making the tax system purposefully pro-business and fine-tuned to ensure it is internationally competitive. Enumerating third mission activities, they provide the following grouping of activities: (a) Technology Transfer & Innovation activities; (b) Continuing Education activities, and (c) Social Engagement activities. They explore how the activities within the grouping of Technology Transfer & Innovation are those most directly associated with economic development.

Completing this part in Chap. 12 with a focus on the restructuring of higher education in the United States, Steen Hyldgaard Christensen examines how the corporatized public research university came about, its distinctive features, and considers the costs and benefits to the public good of commercializing teaching, research, and service. He explores how the dominant economic discourse of neoliberalism originating in the 1970s and the associated discourses of "new public management" from the 1980s have created a tension between two dominant institutional logics of higher education in university restructuring, namely those of the university as a social institution and the university as an industry. He identifies how the relationship between the two institutional logics or models of higher education can be conceptualized in terms of a *social charter* between higher education and society. *The communitarian philosophy of the public good* is reflected in a social and public charter associated with the traditional model of higher education. *The neoliberal philosophy of the public good* promotes an individual and economic charter, resulting in the industrial model of higher education. Finally *the utilitarian model of the public good* advocates a changing and contested charter that is a blending of both the traditional and the industrial models of higher education. He concludes that a precondition for the alternative utilitarian charter to succeed is that students and faculty will have to develop ideas with respect to the funding of the envisioned alternative and to build broad public support for this vision, as simply expecting the state to supply more money is unrealistic.

1.3 Part III: The Practices of Business and Engineering

Approaching the engineering business relationship empirically the four chapters of Part III interrogate a number of practices related to business and engineering respectively. Even though these occupations are often inseparable, yet questions may be raised as to whether they are distinguishable, how engineers and business managers are perceived by outsiders, and how they perceive themselves. In a paradoxical way, the omnipresence of engineering makes it almost invisible to the public. If engineering and business have a lot of commonality within industry, the main issue remains whether they are dealing with the same questions. For instance what responses do they offer to important, yet often neglected issues like the value aspect of work in industry. The practices of business and engineering and the interplay between them can also be studied by exploring their boundaries, particularly the issues of gender equality in the workplace and the predicament of newly hired engineers beginning new jobs. Exploring these issues constitutes the red thread of contributions to this part. Before presenting the four chapters of Part III in their own rights, it is to be noted that a number of issues raised under this section are unsurprisingly echoed in other parts of the book. Readers of Chap. 13, for instance, should consider Chap. 5 in which the relationship between business/engineering practices and society is treated from an ethical standpoint. Likewise readers of Chap. 14 will find some resonance on the need to broaden the scope of entrepreneurial education across different chapters, particularly in Chaps. 17 and 18. From a different perspective, Chap. 15 which deals with the ideals of social justice and human rights through the theme of gender inequality should be related to the broader concept of social charter developed in Chap. 12. And readers of Chap. 16 on the problematic of newly hired engineers beginning new jobs will find further interest in the conclusions of Chap. 22 regarding the employability of engineering graduates.

In the opening Chap. 13 the Australian academic and philosopher of engineering Erik W. Aslaksen sets out to investigate the questions of how engineering and business practices appear to the public and to analyze their complex association in relation to the economy and society at large. His point of departure is that the relationship between these two activities is characterized by two features, namely the need for business to provide the conditions for generating a return on investment, and the fact that engineering, while applying technology to meet expressed needs, generates new technology, thus providing business with new opportunities. After defining a number of significant concepts, Aslaksen explores the relationship between four functional entities: engineering, industry, business, market, and he argues that what appears to society as being *technology* is largely determined by business. He also highlights the difference between science and engineering in the way they are perceived by the public: while science ranks high, engineers are paradoxically almost “invisible”. Then he focuses on how engineering and business are interlocked in a strong economic relationship in which technology is the interface, and he observes that the twentieth century tendency to isolate business from engineering not only proved to be inefficient, but also ignored many non-economic issues. He then goes on to introduce the concept of *engineering paradigm* relating to the external conditions under which engineering is practiced, particularly in the interaction with the business process. Due to increasing legal, technological and statutory constraints, he notes that the engineering paradigm is currently undergoing crucial and rapid changes. Finally he concludes that these transformations to the engineering paradigm call for changes to the engineering profession namely through *hybridization*, whereby technology mediates our relationship to our environment. Acknowledging that this raises a number of major questions, the author calls for a restructuring of the engineering profession and its place in the workforce.

The investigation presented in Chap. 14 by the Australian and Irish academics and engineering educators James Trevelyan and Bill Williams respectively, originates in their observation that the engineers seldom perceive the *value creation* of their work even though their contributions create value for their enterprises and their clients. This has led them to review the scarce literature addressing value creation by engineering and business enterprises. First they explore various definitions of value creation from the perspectives of business research, wealth creation, engineering design and engineering education, focusing on the role of technological innovation for the creation of value, and referring to the concept of *creative destruction* put forward by Schumpeter in the early twentieth century. They note that value creation is perceived in an abstract way and is marginal to the engineering discourse. Then, drawing on empirical studies on engineering practice they set out to identify how engineers create and protect value regarding the reduction of investment risk, due commitment and maintenance work. They argue that engineering activities also aim at value protection, avoiding economic value destruction and showing how destruction can occur. Their research reveals that very few engineers are involved in technological innovation and that most of them perform more "ordinary" tasks. The authors stress the need for human interpretation of documents as well as the necessity for engineering and business people to appropriate information in order to make decisions. Finally, from the qualitative analysis of interviews and field observations, they examine areas of research into engineering practice that could lead to considerable financial savings in major enterprises. In so doing they put forward a model of value creation and protection within an engineering enterprise. They conclude that in the absence of awareness on engineering practice there is an urgent need for engineering faculties to broaden the scope of entrepreneurship education to help their students understand how they can create and protect value in different settings.

After noting the shortage of engineers in most countries, the two Irish academics Jane Grimson and William Grimson – both former presidents of Engineers Ireland – open Chap. 15 by asking if there is sufficient diversity in the engineering community to ensure efficient and sustainable solutions to meet the needs of everyone in society. The diversity they have in focus here is gender: they outline that not only women are significantly under-represented in senior positions in organizations but also that the pay gap with men is still a reality today, despite the fact that a number of major sectors like industry, commerce, engineering and academia, have made or are making real efforts to eliminate gender inequality. They also examine why it is essential to address the gender issue and distinguish three reasons for this: the first is based on the principle that social justice and human rights are or should be guaranteed by the work environment, the principle that all careers should be equally open to both men and women being a prerequisite. The second is a matter of parsimony whereby talent should not be wasted by the failure to attract and retain women in the engineering profession especially in a period of shortage of engineers. The third reason is precisely relating to the diversity argument whereby the wide range of different skills, perspectives and experiences can better respond to whatever challenge is to be faced.

Then they set out to identify a number of measures which organizations are taking to tackle the complex task of promoting gender equality. In so doing they consider four key themes: committed, determined and sustained leadership from the top of the organization, working arrangements to ensure better work-life balance, facilitating initiatives to develop future women leaders, and tackling unconscious bias. After analyzing two characteristic case studies they conclude that gender balance will not be attained automatically without such positive interventions as it is rooted in our culture, and that the engineering profession has to take sustained action now in order to be able to meet the needs of society today and tomorrow.

Closing this part with Chap. 16, the American academic Russel Korte explores the relationship between engineering and business from the viewpoint of newly hired engineers beginning new jobs in a business organization, as this complex transition experienced by graduates illuminates the differences they encounter between engineering as they learned it in school and as they practice it in an organization. The author's perspective is that business and engineering are both occupational communities embedded in an organizational context where engineers have to go through a socialization process with business people to learn how to practice and where, as a result, boundaries are more or less blurred while they work together. The chapter reports the findings of a qualitative, inductive case study carried out by the author on a sample of newly hired engineers and Human Resources managers. One of the first results that Korte relates here is that new engineers are more discomforted by the socio-cultural aspects of organizational work than by the technical aspects of "real" engineering work. He then points out to the complexity and ambiguity of engineering practice which depends on the quality of social interactions within the enterprise: social interaction goes beyond pure communication, and is essentially about building relationships and making sense of things, which form the major part of the new engineers' work. Analyzing Korte's surveys a distinction emerges between three types of communities, engineering, business and organizational communities, each of which depends on and comprises the interactions of the other two. He also stresses that, with the rise of innovation and entrepreneurship, traditional forms of organizations have been evolving to more dynamic models based on communities and collaborative networks. He then concludes that the distinctions between business and engineering communities are mainly disconnected abstractions and tend to disappear in the intricacy of organizational work.

1.4 Part IV: Engineering and Business Education

The six chapters in this section explore, analyze, and provide insights and recommendations on the education of the engineer, not simply from a narrow technical disciplinary perspective, but from the more complex perspective of its purposes within a wider business context. Like the other sections in this volume, the thirteen authors who have contributed to these six chapters come from four countries on two continents. Four are Danes, four are Irish, three are Americans and two are

Canadians. Each chapter has focused on engineering education issues evident within their national footprint. Yet each chapter throws up some common messages or findings: that the nature of societal challenges requires a more reflective engineer, that the education of such engineers requires a systemic approach, and that the employability of engineers demands more complex approaches to their education.

Before presenting the six chapters of Part IV individually, there are links worth noting between the chapters in Part IV and those in the earlier sections. Chapter 2, in its discussion of engineering and business management, provides interesting contrasts to Chaps. 17 and 18 regarding the mechanisms by which engineering curricula are broadened with business subjects. Chapters 18 and 19 examine ethics and sustainable development in engineering and technological education; while Readers might also look at Chap. 3 for an alternative perspective in that it argues that the economic imperative for profitable production is a cause of work place accidents. Chapter 22 which examines employability and whether engineering graduates are ready for work can usefully be read in conjunction with Chap. 5 which notes that engineering graduates are largely left to their own devices after graduation with the competences described through ABET and EUR-ACE criteria. For Readers of the evolution of engineering education, and the current trend towards introducing entrepreneurial subjects, Chap. 9 provides an interesting historical Chinese counterpoint to the western examples provided in Chap. 18, and both are worth reading. In examining the arguments set out for broadening the engineering curriculum in Chap. 17, there is value in a review of Chap. 10 in which John Heywood provides an excellent UK historical example of when industry and education shared responsibility for the development of engineering graduates. Erik Aslaksen in Chap. 13 argues that engineering, as a profession, has not responded adequately to changes over the last 50 years, and the Reader might find echoes of this in the pace of change in engineering curricula described in Chaps. 17 and 18. Readers interested in how engineering graduates assimilate in their early careers should compare a Danish study described in Chap. 22 with an American study described in Chap. 16.

In Chap. 17, three Irish academics – Mike Murphy and Pat O'Donnell from engineering education and John Jameson from business education – examine the evidence of whether and how undergraduate engineering students in Irish universities and institutes of technology are exposed to a broadening curriculum from subjects in liberal arts or social sciences. They do this in response to the assertion set out by philosopher Carl Mitcham that the greatest engineering challenge is to cultivate "deeper and more critical thinking … about the ways engineering is transforming how and why we live". In line with Mitcham's critique, the authors construct a hierarchy called the "Mitcham Classification of Engineering Program Enlightenment" and then use this instrument to examine every undergraduate engineering program in Ireland to determine what evidence there is of a systemic approach to broadening through the inclusion of liberal arts or social science courses, including business courses. The evidence would indicate that the academic engineering community in Ireland generally attaches a low priority to the development of a broader context and perspective within engineering students, beyond technical and disciplinary content, and that there is no systemic attention to a broadening agenda. Often the same few courses within a program are used as evidence across a number of accreditation criteria. Business school leaders also point to a low level of collaboration between engineering and business schools, and the underlying rationale appears to be the "engineer identity" that pushes back against inclusion of non-engineering content. The authors note that an argument might now be made that the narrow technical focus of engineering programs may contribute to the general diminution in the role of the engineer from "an expert astride the wheel to a cog on it". There are resonances here with the conclusions set out strongly by Kolmos and Holgaard in Chap. 22 with regard to employability of engineering graduates.

While written independently by Michael Dyrenfurth and the American academic Gary Bertoline respectively, Chap. 18 takes a similar approach to Murphy, O'Donnell and Jameson by examining the educational curricula of BE&T (business, engineering and technology) students within U.S. universities. Dyrenfurth and Bertoline use the terms "pragmatic capabilities" for employer-demanded skills, and "larger outcomes" for the needs of society, to describe the overall set of competences that BE&T students should acquire. The authors first conduct a review of undergraduate programs in the United States in order to confirm that "significant proportions of university undergraduate enrolment are directed towards pragmatic purposes such as engineering, business and technology"; and they subsequently examine the implications of that focus. They next set out to examine the extent to which ethics, corporate social responsibility and "conscientious capitalism" are reflected in plans of study of a selected number of high profile public and private universities. This is comparable in intent to the examination carried out by Murphy, O'Donnell and Jameson in Chap. 17 to determine broadening content within Irish programs of study, including holding interviews with selected deans and leaders. The results found by Dyrenfurth and Bertoline indicate that ethics is covered widely, but there is less evidence found for corporate social responsibility (CSR) and conscientious capitalism. Interestingly, within the U.S. it would appear that programs are more responsive to accreditation-driven requirements than the Irish authors found. Chapter 18 describes in considerable detail two exemplars of systemic change. These are Olin College, which perhaps provides a unique example of designing a university including its curricula from a student-oriented set of requirements, and the Purdue Polytechnic Institute, which provides an example of transformative change within an established college of technology. The authors conclude by noting that 'bolt-on' approaches to broadening the curriculum will not work and systemic transformation is required.

In Chap. 19, Canadian scholars Lovasoa Ramboarisata and Corinne Gendron also address ethics education, CSR and sustainable development (SD) education at the taught postgraduate level in Canada. They examine business schools and their role in educating engineer-managers via MBA and MS programs. This again can be seen as extending the examination undertaken by the authors in Chaps. 17 and 18. Here in Chap. 19 the authors provide a review of the development of ethics education and the growing debate about its sufficiency arising in recent years from incidents such as bridge and building collapses, water contamination, and chemical leaks. Despite professional codes of ethics and the acceptance that engineers should put the public interest above self-interest, business interest and professional interest, the authors point out that ethical training provided to engineers still stresses their duties to their profession. The authors explore whether education has made the necessary change of direction, or turn, to accommodate the demanding concepts of CSR and SD. What they report finding, however, is that this critical turn has not yet been made to go beyond instrumental ethics, loyalty to businesses, and moral righteousness towards the profession. Ramboarisata and Gendron report that the "business-case" approach remains dominant and broadening teaching beyond this approach is largely still absent. They further report data that show integration of these topics into curricula as non-significant, and that stand-alone courses cannot meet the "ensemble of objectives identified". The authors provide an exemplar course that they designed and teach for an MBA and Technology Management program in Montreal. Through the authors' pedagogical choices, their students have become reflective practitioners.

Chapter 20 focuses on experiences with changes in both the conception and the curriculum of engineering education: the "Design & Innovation Program" implemented at the Technical University of Denmark (DTU) in 2002. The Danish academics Joakim Juhl and Anders Buch draw a historical framing: how, after World War II, public investment in fundamental research first was seen as necessary to protect the special status and independence of research, but gradually the emphasis shifted seeing science as a political instrument, with economic growth as a key performance indicator. Almost simultaneously, views on the internal functioning of science were changing too: instead of focusing on the demarcation of a proper ethos of science (in the line of e.g. Robert Merton and Karl Popper), science came to be seen as a more socially embedded activity: trans-disciplinary, context-aware, and more reflexive ("Mode 2-science"). A final impulse for the development of the Design & Innovation Program was constituted by legislative measures in Denmark. Although officially framed as an "opening up" of universities "outwards to society", and an improvement of universities' "decision-making competence", the changes seemed to have financial self-sustainability of universities as their leading idea. The Design & Innovation Program was developed as a response to that. It combines creative, synthesis-oriented competences, innovative, socio-technical competences and reflective technological engineering competences. The unique and rather atypical profile of this program was attractive to incoming students, and at first the program appeared very successful. In the long run however, it was difficult to maintain the program at its original pace. Juhl and Buch end their chapter by drawing some lessons concerning the entanglement of engineering and business, the normative shifts that occur when marketability is introduced as a quality criterion both for engineering and for academia, and the contingencies and situated nature of how innovations are implemented and evaluated.

In Chap. 21, the American engineering educationalist and philosopher of engineering Alan Cheville and English academic John Heywood take a more analytic and contemplative stance on reforms of engineering education. First, they challenge the traditional view of engineers as "problem solvers". The term "problem" is far too static and one-dimensional to describe the situations engineers have to deal with. They prefer talking about “tensions”: this is a better rendering of the multidimensional, dynamic and dialectic nature of engineering work. In an organization, tensions often arise as the result of differences in “credo” of the members, a credo being a set of beliefs, attitudes and values that may or may not be directly in line with the official policy of the organization. Engineers, like many other collaborators, have to operate within the tension of these different credos. But they are seldom well prepared for this ill-defined situation that seems to require continuous negotiation. The authors argue in favour of an engineering education combining the traditional, linear problem-solving competences with the more subtle, context- and communication-aware competences that would prepare young engineers for their work in real organizations. They use the metaphor of the “real” and “imaginary” components of complex numbers, well known to engineers; both components are necessary to allow the possibilities of complex mathematics to be fully deployed. The hitherto “hidden curriculum” of engineering education should therefore at the same time be adapted and be made more transparent, in order to incorporate and combine both components. And even in the very act of reforming their curricula, educators and their leaders should combine the pragmatic straightforward problem solving approach, with the awareness of the never completely solved set of tensions within which they operate. In this way, the proper professional value of engineering can be protected against the mono-dimensional finance-driven approach that is present in many policy issues, in education as well as in the rest of society.

With the search for employment, young engineers are immediately in the very middle of the engineering-business nexus. In the final chapter of this book, the Danish academics and engineering educators Anette Kolmos and Jette Egelund Holgaard report on the results of an extensive survey (taken in Denmark between 2010 and 2015) on how young graduates perceive the way their education prepared them for the labor market. First of all, the authors are well aware of the conceptual discussions about the components and the idea of “employability”, especially when terms like “generic skills”, “transferable skills”, “core skills”, “soft skills”, etc. are used. Equally, they are aware of methodological issues in the set-up of surveys, and of the difficulty of interpretation of the answers, often also depending on how the questions were framed or formulated. Finally, it also appears that what students or young graduates expect to be important for their first employment, may very well differ from what employers (and educators, and other stakeholders) expect. Kolmos and Holgaard comment *inter alia* on how the students’ self-perception of their competences and their future employability changes when they move through their study career, and on the role of prolonged internships.

References

Bakan, J. (2005/2004). *The corporation: The pathological pursuit of profit and power.* London: Constable an imprint of Constable & Robinson.

Berle, A. A., & Means, G. C. (2009/1932). *The modern corporation and private property.* New Brunswick: Transactions Publishers.
Braverman, H. (1974). *Labor and monopoly capital: The degradation of work in the twentieth century*. New York: Monthly Review Press.
Chandler, A. D. (1977). *The visible hand: The managerial revolution in American business*. Cambridge, MA: The Belknap Press of Harvard University Press.
Colby, A., Ehrlich, T., Sullivan, W. M., & Dolle, J. R. (2011). *Rethinking undergraduate business education: Liberal learning for the profession*. San Francisco: Jossey-Bass A Wiley Imprint.
Davis, M. (2009). Is engineering a profession everywhere. *Philosophia, 37*, 211–225.
Khurana, R. (2007). *From higher aims to hired hands: The social transformation of American business schools and the unfulfilled promise of management as a profession*. Princeton: Princeton University Press.
Layton, E. T. (1971). *The revolt of the engineers: Social responsibility and the American engineering profession*. Cleveland: The Press of Case Western Reserve University.
Locke, R. R., & Spender, J. C. (2011). *Confronting managerialism: How the business elite and their schools threw our lives out of balance*. London: Zed Books.
Martin, M. W., & Schinzinger, R. (2000). *Introduction to engineering ethics* (2nd ed.). Boston: McGraw-Hill Publishing Company.
Micklethwait, J., & Wooldridge, A. (2003). *The company: A short history of a revolutionary idea*. London: Weidenfeld and Nicolson.
Noble, D. F. (1977). *America by design: Science, technology, and the rise of corporate capitalism*. New York: Alfred A. Knopf.
Realin, J. A. (1985). *The clash of cultures: Managers and professional*. Boston: Harvard Business School Press.
Veblen, T. (2007/1923). *Absentee ownership: Business enterprise in recent times: The case of America.* New Brunswick: Transaction Publishers.
Veblen, T. (2009/1921). *The engineers and the price system. Introduction by Daniel Bell.* New Brunswick: Transaction Publishers.

Steen Hyldgaard Christensen MA in Danish Language and Literature and the History of Ideas from Aarhus University, PhD in Engineering Education Research from Aalborg University. Until 2014 senior lecturer at Aarhus University. Since 2014 Adjunct associate professor at Aalborg University. He is lead editor and co-author of six edited volumes: *Profession, Culture, and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives* (Springer 2012), *International Perspectives on Engineering Education*: *Engineering Education and Practice in Context. Volume I* (Springer 2015), and *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context. Volume II* (Springer 2015). Besides he has co-authored *A Hybrid Imagination: Science and Technology in Cultural Perspective* (Morgan & Claypool Publishers 2011) together with Andrew Jamison and Lars Botin. In addition he has published a number of articles on engineering epistemology, culture and higher education. Current research interest: Dynamics in higher education restructuring, Thorstein Veblen, and the tension between engineering and business.

Bernard Delahousse MA in English Language and Literature, Faculté des Lettres de Lille, France. Ex-lecturer in English for Specific Purposes for Engineering students at Université Lille 1 Sciences et Technologies, France. Head of International Office at IUT "A" Lille 1 (1987–2004). Co-editor and co-author of three previous books resulting from international projects initiated and coordinated by S. H. Christensen: *Profession, Culture and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica

2009). Co-author of a further book coordinated by S. H. Christensen: *International Perspectives on Engineering Education: Engineering Education and Practice in Context. Volume I* (Springer 2015). Chief editor of *Les Langues Modernes*, the journal of the French Association des Professeurs de Langues Vivantes (APLV), 2007–2010, then co-editor 2011–2013.

Christelle Didier BS in Electrochemistry Engineering, MA in Education, PhD in Sociology from Ecole des Hautes Etudes en Sciences Sociales (EHESS) Paris. From 1993 to 2013 Assistant Professor at Catholic University of Lille, France, Ethics Department. Assistant Professor, Université de Lille, Département des sciences de l'éducation UFR DECCID. Co-author of *Ethique industrielle* (DeBoeck, Brussels, 1998) and *International Perspectives on Engineering Education* (Springer 2015); author of *Penser l'éthique des ingénieurs* (PUF, Paris, 2008) and *Les ingénieurs et l'éthique. Pour un regard sociologique* (Hermes, 2008). She has published many articles on ethics and social responsibility in the engineering profession and education, and on the engineering profession's values (from interviews and extensive surveys). Research areas: engineering ethics and values, including historical, cultural and gender perspective, sustainable development and corporate social responsibility, social responsibility.

Martin Meganck MSc in Chemical Engineering from Ghent University, PhD in Chemical Engineering and MA Moral Theology both from KU Leuven. Lecturer in Philosophy and Ethics in the Faculty of Engineering Technology at KU Leuven in Ghent. Teaching areas: Philosophy of Science, Philosophy of Technology, Professional and Business Ethics, Research Integrity.

Mike Murphy PhD and MEng degrees in electrical engineering from Stevens Institute of Technology. Prior to that he graduated with an Honours Diploma in Electrical Engineering from Dublin Institute of Technology, and BSc(Eng) Honours Degree from Trinity College Dublin. He is a Fellow of Engineers Ireland and a Member of the Institute of Electrical and Electronics Engineers. He is President of the European Society for Engineering Education (SEFI) and is past Chair of the European Engineering Deans Council. He commenced his industry career with AT&T Bell Labs in New Jersey, and later worked with Bell Communications Research before returning to the academy in 2002, when he joined Dublin Institute of Technology as Director and Dean of the Faculty of Engineering. In 2009 he accepted responsibility for the newly formed College of Engineering & Built Environment at Dublin Institute of Technology, which he led as Dean until January 2014. Mike is currently the Academic Registrar at DIT and is Director of Academic Affairs, Digital Campus & Learning Transformation.

Part I
Engineering and Business Value Systems

Chapter 2
Engineering and Business Management: The Odd Couple

Michael Davis

Managers think in quarters; engineers, in decades.
—Anonymous

What is in opposition is in concert, and from what differs comes the most beautiful harmony.
—Heraclitus

Abstract This chapter has four main parts: the first sketches the changing relationship between engineering and business management; the second describes some differences between the response of business schools to this relationship and the response of engineering schools, especially the difference in their respective courses in "ethics"; the third part draws from the first two a statement of a major problem in relations between engineers and business managers, that is, combining business-management-as-a-mercenary-calling with engineering-as-a-profession; the fourth part proposes a response for business schools to that problem, especially the introduction of the concept of "managing *with* professionals". Engineers and business managers work together best when they understand the value of the ways in which they differ.

Keywords Engineer · Manager · Ethics · Standards · Profession

M. Davis (✉)
Humanities Department, Illinois Institute of Technology, Chicago, IL, USA
e-mail: davism@iit.edu

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_2

2.1 The Changing Relation

The Odd Couple is a play (and movie) about a cohabitation that seemed in prospect certain to fail. When fussy Felix became suicidal over his impending divorce, his best friend, disorderly Oscar, took him in. Within days, Felix and Oscar were finding each other hard to live with. *The Odd Couple* is a serious comedy about the benefits and costs of that “marriage of convenience”.

There are at least three reasons *The Odd Couple* seems to me a useful metaphor for the long cohabitation between engineering and business management. The first reason, and least important, is that Felix seems to have the engineer’s typical urge toward order and material improvement; Oscar, the manager’s typical tolerance of changes of plan and imperfection. Felix is shy and socially awkward; Oscar, talkative and socially adept. The metaphor has a visceral appeal. Second, their cohabitation depended on mutual interest. Oscar lived alone in a large apartment that divorce had emptied of wife and child and his housekeeping had turned into a health hazard. The cohabitation would not have lasted for as long as it did had Felix not needed Oscar’s company and housekeeping as much as Oscar needed a place to live and someone to listen to him try to understand why his marriage had fallen apart. Third, and most important, both Oscar and Felix changed over time as a result of living together. Both were better people when they ended their cohabitation than when they began it. Each benefitted from the compromises, experiments, and revelations that their cohabitation forced on them.

The last reason I gave for taking *The Odd Couple* as a useful metaphor for the relationship between engineering and business management was that the odd couple’s relationship changed over time, benefiting both. I counted that reason as the most important because scholars tend to overlook how much the relationship between engineering and business management has changed in the two centuries since engineers first entered business in significant numbers—and that change tells us something important about both engineers and business, especially about the ways in which they benefit from the relationship.

Two centuries ago engineers were as likely to be independent consultants hired for a job as long-term employees. Like the Roeblings, those early engineers would have had a post-secondary degree in engineering. Business managers, in contrast, were then typically proprietors (“capitalists”) educated in the “school of hard knocks”. So, for example, Cornelius Vanderbilt (1794–1877), the railway magnate and one of the century’s richest men, ended his formal education at age 11. Most of what he knew of business he learned from running his own, starting with a ferry service he began at age 16. Such too were the managers that Thorstein Veblen seems to have had in mind in *The Engineers and the Price System* when he described the “business man” of the nineteenth century as one who “came more and more obtrusively to the front and came in for a more and more generous portion of the country’s yearly income which was taken to argue that he also contributed increasingly to the yearly production of goods” (Veblen 1921, p. 28). Veblen contrasted these businesspeople with the new breed of “financial manager” who “under the limitations to which all human capacity is subject" were—because of the "increasingly exacting discipline of business administration"—"increasingly out of touch with that manner of thinking and those elements of knowledge that go to make up the logic and relevant facts of mechanical technology" (ibid. pp. 39–40). The "entrepreneur" of old was evolving into a mere "chief of bureau", an employee knowledgeable about finance but ignorant of technology in a way the older entrepreneurs were not (ibid. p. 41). The new business managers were bureaucrats much like their counterparts in the civil service.

A close reading of *The Engineers and the Price System* will, I think, reveal that Veblen knew little about engineers as such. Indeed, what he sometimes calls "production engineers" (ibid. p. 53), he also calls "technologists" (ibid. p. 61). The list of "technologists" varies a good deal. For example, in one place (ibid. p. 44), it is "industrial experts, engineers, chemists, mineralogists, technicians of all kinds"; in another (ibid. pp. 60–61), it is "inventors, designers, chemists, mineralogists, soil experts, crop specialists, production managers and engineers of many kinds and denominations". For Veblen, the important contrast was between "financial managers" whose focus is on making a profit and "technologists", including technically trained managers, whose focus is on increasing the quantity and quality of goods, reducing waste, and otherwise adding to society's wealth.

Nonetheless, Veblen did identify an important problem in the relationship between engineers, by then already mostly employees, and business management, by then also mostly employees, an increasing difference between their respective skills, knowledge, and aspirations. The financial manager's focus on profit might often "sabotage" (Veblen's word) the efficient production of useful goods that engineers typically seek. No doubt, it was at least in part this difference between financial managers and engineers, even engineers ranking high in a large corporation, that contributed to what Edwin Layton called "the revolt of the engineers" (Layton 1971).

The story of the business-engineering nexus does not end with that revolt, of course. In the century since 1921, the number of engineers working in business has grown into the millions while the other "technologists" Veblen mentioned now number only in the tens of thousands. Engineers (along with computer scientists) are now central to most large businesses to a degree most other technologists are not. What gave engineers this preeminence? The answer is obvious: the ways in which engineers differ from both business managers and other technologists.

Over the last century, business management became a popular field of study in universities. Indeed, many managers today have an advanced degree, typically a Masters of Business Administration (MBA), while their engineers typically have only a bachelor's. Business management has itself become a science-based technology, though one resting on economics rather than (as engineering does) on physics and chemistry.

Yet, the division that Veblen remarked has not gone away, merely changed. In the 1920s, management ("business administration") seemed destined to join architecture, engineering, law, medicine, nursing, social work, and the like as a profession. Schools of business management taught students that business should seek to serve society, not simply make a profit (Abend 2013). But, by the 1960s, it was already clear that business management was *not* going to be a profession (in the sense it had once aspired to). Business managers were happy to declare that their primary loyalty was to their employer; their primary goal, to maximize their employer's profit. Indeed, some scandals of the 1950s, such as price-fixing in the electrical industry, suggested that managers might believe that loyalty to employer overrode even legal and moral obligations. Senior managers not only broke anti-trust laws for their employers but also lied about it to the press, Congress, or the courts (Herling 1962).

The introduction of "business ethics" into the curriculum of business schools a decade later was in fact a re-introduction. Courses under that name (or near synonyms) had existed in many elite business schools as early as the second decade of the twentieth century, though most seem to have vanished by 1950 (Abend 2013). Yet, the new business ethics differed from the old in at least two notable ways. First, the new business ethics developed as a field of research as well as a course of study. There were soon several academic journals (as well as several textbooks and monographs) (DeGeorge 1987). Second, almost from the beginning, philosophers seem to have had an important part in both the research and teaching of the new business ethics.[1] These philosophers seem to have drawn on philosophy's recent experience with medical ethics, especially its emphasis on resolving ethical problems case by case rather than restating old reasons to accept a predetermined answer. The new business ethics was analytical rather than homiletic. But, like the old business ethics, the new did not seem to be a "revolt of the managers" so much as a revolt of their employers, the public, and the government, a response to scandals in which educated managers thought they had done all they should when they sought (more or less successfully) to maximize short-term return on investment (as they had been taught).

According to some common sociological definitions of "profession" (advanced education, high income, and so on), business management was a profession well before 1960. Yet, by the definition that the professions themselves implicitly accept, business management had long since ceased even to aspire to be a profession (Khurana 2007). Management was definitely not a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a moral ideal in a morally-permissible way (a discipline) beyond what law, market, morality, and public opinion would otherwise require (Davis 2009). Maximizing return on the capital of one's employer is not a moral ideal (an objective all rational persons recognize as good); indeed, maximizing return on investment may not even be the objective of the manager's actual employer. If we take corporate "vision statements" seriously, many employers seek only a reasonable return on their investment so that they can continue to provide a useful product or service.

Rather than becoming a profession, business management had devolved into a mere "money-making calling" in at least two respects. First, of course, managers understood themselves as competing with each other to make as much money as

[1] The only philosopher I have come across in the old business (and professional) ethics is Carl F. Taeusch 1926.

legally possible for their respective employers. Profit was the chief measure of their success. The good of society was no longer understood as even among their objectives (though they might point to the social good they happened to do as a reason to be allowed to go on seeking profit). Second, each manager typically understood herself as a mercenary rather than a professional, that is, as a mere individual seeking to make as much money as possible herself, not as a member of a group seeking to improve the skills, conditions of work, reputation, or the like of their group's common discipline. To have the loyalty of such a manager, an employer had to offer the proper "incentives", especially a high salary, bonuses for achievement, and opportunities to do work leading to "advancement", that is, to a position with an even higher salary and bonuses. We can measure business's increasing awareness of management as a mercenary calling not only by the increasing size of managers' individual income relative to that of other employees but also by the increasing share of that income coming from bonuses (and other incentives) rather than from base salary.

Unlike the old business ethics, the new was to be not so much an alternative to the money-making conception of management as a supplement to, or constraint on, it. Money-making management was to be bridled in certain ways (for example, by the employer's code of ethics); its energies redirected in other ways (for example, by replacing the "single bottom line" of profit with the "triple bottom line" of profit, social responsibility, and environmental responsibility).

2.2 Business Ethics Versus Engineering Ethics

In principle, business ethics could be (a) about how individual employees, including managers, should fulfil their moral obligations as employees, citizens, and human beings ("micro-ethics"), (b) about how businesses should conduct their affairs within the bounds of morality, managers understood as mere agents of their employers ("meso-ethics"), (c) about what society should expect of business and how it might go about getting it ("macro-ethics"), or (d) some combination of these. (Davis 2010) In practice (judging from the textbooks), courses in business ethics are today primarily about how businesses, especially large corporations, should conduct themselves; they are a kind of meso-ethics.

A typical course in business ethics today will have four divisions. First, there will be an introduction to the central concepts of business ethics, such as moral theories, "stakeholder analysis", law, the market, and the moral status of a corporation (and the people it employs). Second, there will be discussion of moral issues that arise within the business, such as affirmative action, conflict of interest, confidentiality, employment at will, drug testing, fair wages, insider trading, occupational health and safety, sexual harassment, and whistleblowing. The emphasis in this second division will be not on how individual managers, much less individual employees, should deal with particular situations involving such issues, but on how the business as a whole should respond to that sort of problem (the managers acting as faithful agents of the business). Third, there will be discussion of moral issues that arise between a business and its community, competitors, customers, regulators, suppliers, or others outside. Among these issues will be truth in advertising, influencing government ("lobbying", facilitation payments, and bribery), intellectual property, spying on competitors, legally permitted pollution, mergers and acquisitions, product safety, and social responsibility (especially, treatment of neighbors, suppliers, and society at large). The fourth division will reconsider the first three divisions in the context of "globalization", especially the variety of local customs, cultural differences, and different legal systems that a business is likely to meet when it establishes sales offices, factories, or subsidiaries in another country, especially a relatively poor country. Should a business take its ethics with it wherever it goes, change its ethics to suit the customs, culture, or laws of each country in which it operates, or respond in some other way? (Compare DeGeorge 1987).

Occasionally, a course in business ethics may discuss "ethics infrastructure": ethics audits, ethics officers, ethics "hot lines", and so on. This discussion may include corporate codes of ethics, codes of ethics adopted by trade associations, or the like. But I have yet to see a text in business ethics with anything to say about *professional* ethics, much less one noting that many employees in any large business (actuaries, chemists, lawyers, and so on) will belong to a profession and therefore have moral obligations in addition to those of ordinary employees. A few social scientists specializing in business have, it is true, noted the presence of large numbers of professionals in business (See, for example, Shapero 1985; or Raelin 1986). But, to this day, courses in business ethics seem to divide the inside of a business into "management" (a collection of the employer's agents) and employees (mere individuals), with management answering to "the stockholders" (or "stakeholders") and controlling "the employees".

I speak here only of texts in (general) business ethics, texts designed to train "managers". Many business schools have programs in accounting, finance, human resources, or the like that have their own course in ethics (the ethics of the profession in question). These courses have their own texts, ones much more like texts in engineering ethics than the typical texts in business ethics.

Like much of the business school curriculum, the course in business ethics will typically be organized around in-depth study of "cases", some fictional but most actual. Some are law cases but most are a summary of facts or a collection of documents. Among cases often included are some that are quite old, such as The Ford Pinto (from the 1970s) or The Space Shuttle Challenger (from the 1980s). Others are relatively new, such as the tardy 2014 recall by GM of 800,000 small cars to have their ignition fixed to resolve a safety problem, or the 2015 scandal concerning VW's modification of its diesel's software so that pollution controls worked during tests but not on the road. Like these four cases, many standard business ethics cases also appear (or at least could appear) in texts in engineering ethics. Such shared cases are, in fact, evidence for a close connection between business ethics and engineering ethics.

Nonetheless, in the US at least, the course in engineering ethics arose (or, more accurately, re-arose) more or less independently of business ethics, though at about the same time. The same seems to be true of engineering ethics as a field of academic research. (Davis 1990) There are doubtless many reasons for that independence. Among the most obvious are these four: First, engineering schools and business schools, even when located on the same campus, have historically had little to do with each other. Second (and perhaps explaining the first), the culture of business schools is quite different from that of engineering schools (as Veblen would have expected). For example, engineering students are typically much more interested in making things work than business students are; business students, much more interested in how people work. Third, though philosophers were as involved in early work in engineering ethics as in the new business ethics, they were rarely the same philosophers. Both business ethics and engineering ethics are (what philosophers call) "applied philosophy". Applying philosophy to a practice outside philosophy means learning a good deal about the practice. Learning enough about business to be useful to businesspeople probably left little time to learn enough about engineering to be useful to engineers—and *vice versa*. The economics of applied philosophy made it likely that there would be little overlap among philosophers in fields developing at about the same time. Fourth, the two fields tended to attract different kinds of philosophers. So, for example, philosophers interested in social justice seem more likely to have become involved in business ethics; those interested in technology or professions, to have become involved in engineering ethics.

Not surprisingly, then, a course in engineering ethics typically differs in fundamental ways from a course in business ethics. Perhaps the most important of these differences is that engineering ethics typically is a course in professional ethics (a kind of meso-ethics distinct from business ethics). There is an attempt to define "profession" and explain how engineering fits that definition. There is a discussion of engineering's code of ethics and practice applying the code to particular practical decisions ("problems"). (Engineering ethics texts typically reprint at least one code of engineering ethics.) There may even be an introduction to engineering's professional associations, technical standards, and licensing bodies. The overall message is that engineers have a moral obligation to their profession at least as weighty as their obligation to their employer: engineers are *not* "mere employees".

The teaching of engineering ethics is, however, not limited to a course in that subject. Such teaching goes on both explicitly and, more often, implicitly, in engineering's "technical" courses. Though I have written a good deal about explicitly integrating professional ethics into engineering's technical courses, I believe explicit integration is still relatively uncommon. So, I shall say no more about it here (For more, see, for example: Davis 2006; Davis et al. 2016). What does seem to be a common practice is the *implicit* integration of engineering ethics in at least some of engineering's technical courses. The integration goes on using such terms as "accuracy", "documentation", "efficiency", "reliability", "safety", and "sustainability". Such terms denote technical standards in engineering, standards government, engineering associations, or independent standard-setting bodies have elaborated in considerable detail. In general, engineering's technical standards are ethical insofar as they are morally binding guides to conduct that each engineer (at her rational best) wants every other engineer to follow even if the others following them would mean having to do the same. For engineers, their profession's ethics is (or, at least, should be) not so much a supplement or constraint on their main pursuit as a component of what they seek to accomplish. To be a good engineer is to help improve the material condition of human beings in the way engineers typically do, not to make a lot of money for self or employer (though, of course, money is always welcome). Accuracy, documentation, efficiency, reliability, safety, sustainability, and the like are part of good engineering, not a mere constraint on what engineers as such do.

Engineering is sometimes described as a "captive profession", as if engineering were once free like most other professions but now only survives in cages, the large organizations in which engineers now typically work, especially modern business corporations (Noble 1977; Goldman 1991). This description of engineering seems to be mistaken for at least five reasons.

First, much of the plausibility of claims about engineering's captivity seems to arise from confusing the function of engineers (building, designing, and so on) with the discipline of engineers (the special knowledge, skill, and judgment, largely taught in engineering school, that engineers bring to building, designing, inspection, and other work engineers typically do). While the function of engineers has been carried on in many societies, including some quite ancient, and under many names (builder, inventor, machinator, mechanic, munitor, technician, and so on), the discipline seems to be much newer, originating in the French army in the late 1600s. Engineering became a civilian profession only in the 1800s when civilian technology, beginning with railroads, became demanding enough to benefit from engineering's special discipline (Davis 1995). While some of those who have functioned as engineers in earlier times may have done so free from any large organization, those sharing the discipline of engineering have not. (A disciple is defined by certain sorts of knowledge, skill, and judgment passed by teachers to students in an unbroken line from one generation to the next.)

Second, because professions are, by definition, ways to earn a living, no profession can long survive without employers, people to pay the cost of carrying on the profession. Even the freest profession must generally do what its employers want or cease to exist. Engineering has never been free of employers—nor could it be without becoming an (expensive) avocation rather than a profession. That is as true of other professions as of engineering.

Third, engineers have never been able to do much on their own. Even in the days when a lone engineer might oversee a siege, he could do little without the large organization that determined where he employed his siege craft and provided the labor, supplies, and protection necessary to carry out his plans. Today, good engineering generally requires the resources of a large organization, including the cooperation of other engineers. An engineer alone is, and always has been, more or less useless, an engineer only in the sense of having the potential to do engineering.

Fourth, all this is as true of engineers working for government, a socialist enterprise, or a non-profit as of engineers working for a business. The word "captive" in "captive profession" sounds bad but in fact tells us nothing about engineering.

While profit is a constraint on engineers working for a business, it corresponds to the constraint of budget characteristic of government, socialist enterprise, or non-profit. Business has not captured engineering—in any interesting sense of "capture". Engineering is, instead, a profession having a symbiotic relation with large organizations, whether for-profit or not.

Fifth, the idea that projects that are "intrinsically technically challenging and interesting but without a market" (Holt 2001, 498) would have precedence in engineering but for the profit-motive of business seems to involve at least two mistakes. One mistake is the assumption that only business constrains engineers in some such way as this. In fact, every organization for which engineers are likely to work must direct their efforts away from the merely technically challenging toward what is useful, however prosaic. Few engineers are free to do what they want even in a government laboratory. Few engineers are hired to do "pure science". The other mistake is to assume that the intrinsically technically challenging project should be the aim of engineers once freed of practical constraints. The moral ideal engineers seek to serve is (more or less) improving the material condition of human beings, not high-tech at any cost. A project without a market is unlikely to improve the material condition of human beings. It is therefore unlikely to count as good engineering. Hence, it is hard to know what the term "pure engineering" might mean.

2.3 Importance of Disagreement Between Engineers and Managers

The line between engineers and business managers is not as sharp as the discussion so far may suggest. The manager overseeing the work of any particular engineer is likely to be an engineer as well (whether or not holding a business degree in addition to an engineering degree). Indeed, even the senior management of many large businesses will include a significant number of engineers. For example, of Lockheed Martin's eight vice presidents, three are engineers[2]; of GM's twenty-four senior officers, seven are engineers.[3] Many disagreements between engineers and business management are (in part at least) disagreements among engineers.

But beside, below, or above such "engineer-managers" will be managers trained only in accounting, computer science, industrial design, law, marketing, or another

[2] See biographies of: Patrick M. Dewar, Executive VP; Dale P. Bennett, VP for Mission Systems and Training; Richard F. Ambrose, VP for Space Systems, http://www.lockheedmartin.com/us/who-we-are/leadership.html (accessed October 17, 2015).

[3] See biographies of: Mary T. Barra, Chief Executive Officer; Alan Bately, Executive Vice President and President, North America; Alicia Boler-Davis, Vice President of Global Connected Customer Experience; James B. DeLuca, Executive Vice President, Global Manufacturing; Grace Lieblein, Vice President, Global Quality; Karl-Thomas Neumann, Executive Vice President & President, Europe; Mark Reuss, Executive Vice President, Global Product Development, Purchasing and Supply Chain; Matt Tsien, Executive Vice President and President, GM China. http://www.gm.com/company/aboutGM/GM_Corporate_Officers.html (accessed October 17, 2015).

non-engineering discipline. Many of the ethical problems engineers face in practice arise (as they did in Veblen's day) as a disagreement between engineers and non-engineers. Some of these disagreements set engineering against finance (such as the constraints of budget), but some may set engineering against aesthetics (what designers think looks good), culture (what marketing thinks customers expect), or law (what lawyers think necessary to protect the employer against legal liability). Products of a modern business (like products of government) typically involve complex negotiation between many "stakeholders", some of them inside the business.

It is easy to assume (as Veblen did) that when there is disagreement between engineers and "financial managers", the financial managers must be wrong. They are wrong sometimes, of course, but certainly not always. Some engineering solutions may be both beyond an organization's resources and, while morally desirable, not morally required. Much of the time, the right answer, or even the least bad answer, about what to produce or how to produce, sell, maintain, or dispose of it may be unclear, especially at first. The work of business is increasingly carried on by interdisciplinary teams because no discipline has a monopoly on answers to the complex problems modern businesses face.

What has been called "the revolt of the engineers" may be understood as part of a larger and longer negotiation both within engineering and between engineering, its fellow professions, managers, and their common employers concerning what engineering is, what it should do, and why it should do it (Sinclair 1980). The "revolt" focused primarily on two issues: one about management (the power that engineers should exercise in corporate decisions); the other about the welfare of "bench engineers" (their salary, conditions of work, opportunities for advancement, and other reasons they should have for doing their job). Meanwhile, engineers were making themselves increasingly necessary, especially for businesses making or operating complex artifacts, everything from airplanes to skyscrapers. Engineers made themselves increasingly necessary by developing technical standards, publishing them through professional organizations such as the American Society of Civil Engineers (ASCE), and then trying to follow them. The standards were developed to reduce waste, increase safety, protect health, and so on. Insofar as the standards did what they set out to do, they served long-term business interests, tying business to engineering even as engineering seemed ever more subordinate to business. Even as the "revolt" collapsed during the 1920s, a revolution in the relationship between engineers and business management continued: The "master" became increasingly dependent on the "slave".

Consider, for example, the sealed-beam headlight. It was developed by engineers concerned to improve safety on night-time roads. It was adopted as the industry standard in 1939, a time (the Great Depression) when engineers are supposed to have been most subservient to business. The new headlight, though a technological leap, was a natural extension of standards that two engineering associations, the Illuminating Engineering Society (IES) and the Society of Automotive Engineers (SAE), had jointly been working on since 1918. The headlight was developed by engineers at General Electric (GE), especially Val Roper, the leader of an applied research team at GE's Automotive Lighting Laboratory in Cleveland, Ohio. Technical feasibility was established in 1937.

From the perspective of the typical "financial manager", the decisive barrier to adopting the new headlight was, however, not technical but financial feasibility:

> [In] 1937, General Electric, as a diversified company, had no compelling motive to overhaul a segment of their lamp business which was already profitable, growing, and arguably producing state-of-the-art products. In fact, some in the company argued that it would be wrong to require depression-beleaguered Americans to buy and install expensive new headlights. The market would buckle to popular resistance, and G.E. would be left with sizable losses from the venture. (Meese 1982, p. 12)

Roper argued in response that failing to bring the new headlight to market was to continue tolerating the horribly high rate of nighttime automobile accidents. More importantly, Roper was soon drawing on a network of engineers—in GE itself, in American automobile manufacturers (such as GM), in state bodies regulating auto safety, and in headlight manufacturers to whom GE sold light bulbs but with whom GE might soon be competing with its new headlight—to work out a plan to overcome the legitimate worries of the financial managers while simultaneously stressing the importance that the safety of the public should have in the final decision.

Roper credited

> the rapid introduction of the Sealed Beam headlight to the responsiveness and flexibility of General Electric management [primarily senior engineer-managers], the industry-wide cooperation regarding the exchange of technical information at the engineer-to-engineer level, the restraint of A.A.M.V.A. [American Association of Motor Vehicle Administrators] to withhold preemptive new regulation, and the persistent efforts of the S.A.E. Lighting Committee and the I.E.S. Headlighting Committee. (Meese 1982, pp. 16–17)

There is, I suggest, nothing unusual in this story of engineers leading the way in making a business decision except for the scale of the achievement. This story nonetheless has at least three lessons to teach concerning the relationship between engineering and business management (and, indeed, between engineers and managers generally).

The first lesson concerns breadth of vision. It is often said that engineers are narrowly technical while managers, being generalists, see the big picture. While some engineers may be narrowly technical, many are not. As in this story, the difference in vision may not be breadth so much as direction, with engineers looking one way and (financial) managers looking another. The safety of the public is certainly at least as broad a concern as GE's financial welfare. In another respect, however, it is the financial managers who plainly have the narrower vision. Not being professionals, their chief commitment (beyond morality's minimum) must be to their employer. They are expected to look beyond that commitment only if their employer instructs them to. Engineers, in contrast, have commitments extending well beyond their employer, commitments arising from their profession.

The second lesson concerns political skills. Engineers are often thought of as politically helpless while managers are politically astute. The story of the sealed-beam headlight is, however, the story of engineers who were politically astute—at least while working within a network of engineers. The truth is probably that financial managers are good at working with other financial managers but not with "technical people". For dealing with senior management, especially senior managers who are not engineers, the financial managers may be better able to speak the common language—which, after all, is money. But for dealing with outside regulators, or engineers at suppliers, customers, or competitors, engineers may be better able to speak the language—which is more likely to be engineering than money.

The third lesson concerns the relative sterility of financial management. Like the older term "administration", "management" as such is primarily about overseeing, reporting, or making arrangements, not inventing. Engineering, in contrast, is about inventing, improving old artifact or creating new ones. From the perspective of engineers (and the rest of us), financial managers (whether in business, government, or non-profit) will either go along with the engineers, helping with their projects, or be impediments—"saboteurs", as Veblen would have it. Of course, labeling financial managers as saboteurs is not fair, not even in the story of the sealed-beam headlight. The sealed-beam headlight would have saved few lives had it quickly bankrupted GE (or simply not been accepted by auto manufacturers or the public). If a business is to do good in the long term, it must survive in the short term. One important function of business management, especially financial management, is to think about the short term when no one else is thinking about it.

2.4 A Proposal

The forgoing analysis seems to suggest a major change in the curriculum of business schools: Business schools should systematically teach about professions. What they should teach is, however, not best described as "managing professionals" but as "managing *with* professionals". "Managing professionals" suggests that professionals are passive and managers are in control. The addition of "with" suggests instead not only that some managers will be members of this or that profession but that managers must work with professionals, even if the professionals are not themselves managers, rather than merely control them.

Among the topics that should be stressed when teaching managing with professionals is the importance of disagreement between professionals and their managers. Professionals, though experts, are not mere experts. In addition to their special knowledge, skill, or judgment, professionals have commitments different from those of the ordinary manager. Professionals, such as engineers, are in fact hired in part because of those commitments. So, for example, one reason to hire an engineer, rather than an ordinary manager, to supervise safety testing is that engineers are committed to safety in a way ordinary managers are not—whether the business makes the hire because it values safety as such, because the law requires an engineer to supervise certain safety tests, or because the legal department urged the hire to reduce liability should some accident occur. The engineer will serve the employer by carrying out those safety tests according to engineering standards even if the results hurt the employer in the short term. Out of a disagreement between a manager worried about that short-term harm and an engineer concerned to maintain engineering standards may come an agreement satisfying both and better than either original alternative ("the beautiful harmony" of which Heraclitus spoke).

Of course, such agreement is more likely to come out of initial disagreement if the manager has learned how to carry on the discussion necessary to reach such an agreement. A course in business ethics should, therefore, include role-play in which some students play engineers and some play managers engaged in trying to reach agreement that respects the concerns of engineers as well as management. Both business ethics and other management courses should pay more attention to the discussions out of which important decisions, as well as unimportant ones, come. Indeed, I think today's emphasis on "leadership" in business is a mistake. Leaders are typically people who know where they should go and how to get others to follow. In many situations involving engineers, especially the most important, neither managers nor engineers are in a position to lead (in this sense). Like the odd couple, they must work their way to solutions they cannot anticipate, helping each other along. Better than leadership are the compromises, partial solutions, and inventions of cohabitation.

References

Abend, G. (2013). The origins of business ethics in American universities, 1902–1936. *Business Ethics Quarterly, 23*, 171–205.

Davis, M. (1990). The ethics boom: What and why. *Centennial Review, 34*, 163–186.

Davis, M. (1995). An historical preface to engineering ethics. *Science and Engineering Ethics, 1*, 33–48.

Davis, M. (2006). Integrating ethics into technical courses: Micro-insertion. *Science and Engineering Ethics, 12*, 717–730.

Davis, M. (2009). Is engineering a profession everywhere? *Philosophia, 37*, 211–225.

Davis, M. (2010). Engineers and sustainability: An inquiry into the elusive distinction between macro-, micro-, and meso-ethics. *Journal of Applied Ethics and Philosophy, 2*, 12–20.

Davis, M., Laas, K., & Hildt, E. (2016). Twenty-five years of ethics across the curriculum: An assessment. *Teaching Ethics, 16*. (Spring, 55–74.

DeGeorge, R. T. (1987). The status of business ethics past and future. *Journal of Business Ethics, 6*, 201–211.

Goldman, S. (1991). The social captivity of engineering. In P. Durbin (Ed.), *Critical perspectives on nonacademic science and engineering* (pp. 121–146). Bethlehem: Leheigh University Press.

Herling, J. (1962). *The great price conspiracy*. Washington, DC: Robert B. Luce.

Holt, J. E. (2001). The status of engineering in the age of technology: Part I. Politics of practice. *International Journal of Engineering Education, 17*, 496–501.

Khurana, R. (2007). *From higher aims to hired hands: The social transformation of American business schools and the unfulfilled promise of management as a profession*. Princeton: Princeton University Press.

Layton, E. (1971). *The revolt of the engineers*. Cleveland: Case Western Reserve University Press.

Meese, G. P. E. (1982). The sealed beam case: Engineering in the public and private interest. *Business & Professional Ethics Journal, 1*, 1–20.

Noble, D. E. (1977). *America by design*. New York: Alfred A. Knopf.
Raelin, J. A. (1986). *The clash of cultures: Managers and professionals*. Cambridge, MA: Harvard Business School Press.
Shapero, A. (1985). *Managing professional people*. New York: Free Press.
Sinclair, B. (1980). *A centennial history of the American society of mechanical engineers, 1880–1980*. Toronto: American Society of Mechanical Engineers.
Taeusch, C. F. (1926). *Professional and business ethics*. New York: Henry Holt and Company.
Veblen, T. (1921). *The engineers and the price system*. New York: R. W. Huebsch.

Michael Davis MA and PhD in Philosophy, University of Michigan. Professor, Department of Humanities, and Senior Research Fellow, Center for the Study of Ethics in the Professions, Illinois Institute of Technology, Chicago. Before coming to IIT in 1986, he taught philosophy at Case-Western Reserve University, Illinois State University, and the University of Illinois-Chicago. Davis has regularly taught courses in both engineering ethics and business ethics for nearly three decades. Since 1990, he has held four grants from the National Science Foundation to teach faculty how to integrate professional ethics into their technical courses. He has published more than 200 articles and chapters, as well as eight monographs, many on the subject of engineering ethics. His current research concerns the transfer of the idea of profession across cultural boundaries. Recent publications include: *Twenty-Five Years of Ethics Across the Curriculum: An Assessment* [with Kelly Laas and Elisabeth Hildt], *Teaching Ethics* 16 (Spring 2016): 55–74; and *Proving that China has a Profession of Engineering: A Case Study in Operationalizing a Concept across a Cultural Divide* (with Hengli Zhang), *Science and Engineering Ethics* (2016, Nov 23).

Chapter 3
Prisoners of the Capitalist Machine: Captivity and the Corporate Engineer

Eddie Conlon

Abstract This chapter will focus on how engineering practice is conditioned by an economic system which promotes production for profit and economic growth as an end in itself. As such it will focus on the notion of the captivity of engineering which emanates from features of the economic system. By drawing on Critical Realism and a Marxist literature, and by focusing on the issues of safety and sustainability (in particular the issue of climate change), it will examine the extent to which disasters and workplace accidents result from the economic imperative for profitable production and how efforts by engineers to address climate change are undermined by an on-going commitment to growth. It will conclude by arguing that the structural constraints on engineering practice require new approaches to teaching engineers about ethics and social responsibility. It will argue that Critical Realism offers a framework for the teaching of engineering ethics which would pay proper attention to the structural context of engineers work without eliminating the possibility of engineers working for radical change.

Keywords Capitalism · Captivity · Marxism · Critical realism · Engineering ethics

3.1 Introduction

> Capitalism as a socio-economic form of life continues to have overwhelming causal importance in shaping the geographical distribution of economic activity, the life chances of whole categories of people, the availability of policy-options for dealing with pressing economic, social and ecological problems and so on. In the wake of the neo-liberal ascendency and capitalist globalization this is even more inescapably so. (Benton and Craib 2011, p. 209)

E. Conlon (✉)
College of Engineering and Built Environment, Dublin Institute of Technology, Dublin, Ireland
e-mail: edward.conlon@dit.ie

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_3

It seems we are all prisoners of the capitalist machine.[1] Like other categories of people capitalism matters to engineers. And engineers matter to capitalism: economic growth is dependent on a process of continual technological renewal and change. Big corporations, some with value greater than some countries' GNP, with managers, not entrepreneurs, at the centre of them, are the organizational form that has come to represent growth. Therefore, engineers and managers are central features of contemporary capitalist society.[2]

Conflicts between engineers and managers feature in many case studies that engineering students study as part of engineering ethics programs (Lynch and Kline 2000). This chapter aims to situate these conflicts between engineers and managers within the broader forces shaping the employment relationship and the operation of capitalist economies. Critical Realism offers a useful philosophical framework for doing this, given its depth ontology which forces us to focus on underlying structures which shape human practices. Marxism offers one way of understanding these underlying structures and remains the most influential account of the employment relationship within sociological theory and one that has a profound effect on all disciplines concerned with work (Browne 1998; Thompson and Mc Hugh 2002). It will be argued that the aspiration of engineers to hold paramount the welfare of the public is conditioned by an economic system which promotes production for profit and operates through hierarchical organisational forms which shape the relations between engineers and managers. This is not to say that the actions of engineers are crudely determined by the imperatives of profitable production but that, as Althusser might say (see Craib 1992), they are "determined in the last instance" by the requirement of the capitalist mode of production which "shapes behaviour not by fixing exactly what people do but by establishing boundaries and limits" (Korczynski et al. 2006, p.14). I want to emphasise the embeddedness of engineering practice arising from the totality constituted by capitalist society and the structural constraints on the engineers' role and therefore defend the conceptualisation of engineering as a captive profession (Noble 1977; Goldman 1991; Holt 2001; Conlon 2013).

I proceed by discussing some features of Critical Realism and the structure of capitalist economies derived from Marxism. The position of engineers within this structure is then explored. It is argued that although relations between engineers and

[1] My title is inspired by Mike Davis's study of the American working class, *Prisoners of the American Dream,* London and New York: Verso, 1986.

[2] Broadly managers can be seen as those with delegated power to control and coordinate the diverse functions of corporations with the aim of meeting the corporation's goals. While some are also owners, in that they may hold substantial shares in the corporations in which they manage, many do not. Over time and as corporations have become larger and more complex the management function has become more differentiated (Thompson and Mc Hugh 2002). Engineers are a diverse group of technical professionals. While most are salaried employees many are also members of management. Engineers perform diverse functions within corporations. National variations in the processes for reproducing engineering work and engineers has led Meiksins and Smith (1996) to conclude it may be "impossible to develop a definition of what an engineer is, or where the boundaries of engineering lie, which would apply to all industrial capitalist societies" (p. 3). While acknowledging this diversity the focus of this chapter is on the overarching features of capitalist economies and how they impact the work of engineers. While the main focus is on corporations who seek to make profits the analysis has implications for the engineering profession as a whole.

managers have specific characteristics in different capitalist economies they are conditioned by the dynamics of class relations, which create contradictory demands on engineers, but also place limits on engineering practice especially when it collides with corporate priorities. The limits on engineering practice are explored further by an examination of the issues of safety and engineers' roles in addressing climate change, in the context of an increasingly neo-liberal business environment. The conclusion will focus on how Critical Realism can contribute to developing an approach to engineering ethics which will enable future engineers to understand the full range of issues they will be required to address in order hold paramount the health, safety and welfare of the public. To escape captivity engineers will need to confront constraints arising from the business environment.

3.2 Critical Realism

In the social sciences Critical Realism (CR) has emerged as an alternative paradigm to positivism and interpretivism. It combines a realist ontology with an interpretive epistemology: the real world exists independently of our knowledge of it and our knowledge of the world is always fallible as it is shaped by the "social position of knowers" (Carter and New 2004, p. 2). CR argues for the primacy of ontology. In seeking to explain phenomena it offers a distinctive approach. Firstly, a depth ontology: a notion of a stratified reality which includes a distinction between the domain of the real (generative mechanisms), the actual (events) and the empirical (experiences). Structures of objects, at the level of the real, generate mechanisms that facilitate events. Realist explanations connect experience in the empirical domain with structures and processes in the real domain. We are encouraged to look "at deeper structural things that might be the cause of events" (Kotta 2011). This is potentially emancipatory in that it forces us to consider "that certain states of affairs cannot be ameliorated within existing structures" (Collier 1994, p. 10). They must be changed.

While arguing that the social can be studied scientifically critical realists also argue there are differences between the natural and social sciences. Firstly, taking the conduct of experiments as a starting point, CR argues that the kind of closure offered by laboratory experiments is not achievable in the real world. Therefore causal mechanisms must be studied as part of open systems where their effects may be blocked by the operation of other mechanisms (Danermark et al. 2002). Thus their impact is conditioned by the context in which they operate.

Secondly, social structures are maintained through the activity of people. CR offers a particular social ontology focused on the relationship between structure and agency and is committed to an explanatory model "in which the interplay between pre-existent structures, possessing causal powers…and people possessing causal powers…of their own results in contingent yet explicable outcomes" (Carter and New 2004, p. 6). This implies that any investigation can only take place "at the intersection...of agental and structural objects" (Scott 2000, p. 15). Margaret Archer (1995) argues that social theory has come up with unsatisfactory ways to understand this relationship and provides a framework for understanding different approaches by focusing on what she calls varieties of *conflationism.* On the one hand there is downward conflation which emphasises the determining effect of social structures and allows very little role for intentional human activity in explaining social forms. On the other hand there is upward conflation which places undue emphasis on the creative and intentional dimension of human activity. She identifies a third kind of central conflationism, which see agency and structure as "mutually constitutive" and fundamentally inseparable.

CR is committed to *analytical dualism* in that structure and agency are seen as objects of a radically different type possessing different properties and powers (Carter and New 2004). For the latter these include self-consciousness, reflexivity and intentionality. The key properties of social structures are anteriority (they are pre-existing features of the world we are born into) and that they are relatively enduring. Among the powers possessed by social structures are those of enablement and constraint. Thus the tranformative potential inherent in human agency can only "begin to bite when structural contexts....are generally supportive of those potentialities being actualised in some durable form" (Reed 2005, p. 302). In this account social structures are seen to be causally efficacious: "People choose what they do, but they make their choices from a structurally and culturally determined range of options – which they do not choose" (Carter and New 2004, p. 3).

3.3 The Social Structure

This is very much in the spirit of the oft quoted statement from Karl Marx that "Men (sic) make their own history, but they do not make it as they please; they do not make it under circumstances of their own choosing but, under circumstances existing already, given and transmitted from the past" (Marx 1954) and highlights the close affinity between CR and Marxism (Benton and Craib 2011). Marxism offers one way of understanding deeper structures and the underlying mechanisms which shape the operation of capitalist societies and, consequently, business practices.

Drawing on Marx, Douglas Porpora provides a definition of the social structure as "a causal mechanism constituted by the relationships among social positions that account for social phenomena in terms of tendencies, strains and forces inherent in the nexus of these relationships" (1998, p. 340). In the Marxist tradition, he says, the systems of social relationships referred to are modes of production, social positions are class positions and human relationships are class and intra-class relations such as domination, competition and exploitation. In realist terms Marxist analysis seeks to explain the tendential properties of capitalism in terms of its internal structure. Thus the internal structure of capitalism: involving minority ownership of the means of production; production for profit by competing firms operating in a market economy and a class of workers who live by selling their labour power; has certain deleterious tendencies. These include the growth in monopolies and a concentration of wealth, crises of overproduction, the degradation of work and conflicts of interests based on a "structured antagonism...in which the workers' ability to work is deployed in the creation of a surplus that goes to another group" (Edwards 1986, p. 5).

What is useful in this approach is that it takes us beyond the common-sense understanding, endorsed by much mainstream theory, of the wage contract as a fair exchange between freely contracting parties to a focus on the underlying "coercive relations of power and domination which characterises the process of production" (Benton and Craib 2011, p. 137). Domination is seen as intrinsic rather than being pathological or temporary as most forms of organisational analysis might suggest (Thompson and Mc Hugh 2002). We are also encouraged to challenge the view that corporations are rational enterprises pursuing goals to satisfy the interests of all. The focus shifts to how they pursue the interests of elites at the expense of others.

There are a number of elements of a Marxist analysis of the employment relationship that can be noted (Brown 1998; Hyman 2006). Firstly workers are capable of creating greater value than the cost of maintaining them and the means of production. The employer wants to produce commodities that embody surplus value. Worker activity contributes to the production of use value and exchange value which generates surplus value which goes to their employer. Thus the production process is simultaneously a production and valorisation process. Secondly, when they sell their labor workers agree not to expend a particular amount of effort but rather to make their capacity to work available to their employer. Because of this indeterminacy of labor potential control exercised by the employer, or their representatives, is necessary to ensure that the work the workers have been hired to do is actually done. Thus the labor process is organized hierarchically and employers build relations of control into the structure of the labor process. Class divisions are thus institutionalized in the workplace particularly between managers (and engineers) involved in the design and control of work and workers involved in productive activity (Meiksins and Smith 1996; Morgan 1997).

In understanding the issue of control in the workplace it is important to acknowledge the essentially contradictory requirements facing management:

> The function of labour control involves both the direction, surveillance and discipline of subordinates whose enthusiastic commitment to corporate objectives cannot be taken for granted; and the mobilisation of the discretion, initiative and diligence which coercive supervision, far from guaranteeing is likely to destroy. (Hyman 1987, p. 41)

Therefore there is not just one strategy for control, such as Scientific Management and its attendant deskilling as argued by Braverman (1974) and others, such as the engineer Mike Cooley (see Smith 1987), who have drawn on Braverman to argue that there was an inherent tendency in capitalism to use technology to deskill technical workers, such as engineers. There are a variety of control strategies available to managers which are shaped by workers skills, market conditions, technology and also worker resistance. This suggests there are constraints on what managers can do. A narrow focus on deskilling and profit maximisation may undermine the social relations necessary for ensuring successful valorisation (Mac Kenzie 1996). It is not always necessary or possible to eliminate worker discretion and exercise direct and detailed control over work tasks. One typology (Friedman 1977) distinguishes between direct control and responsible autonomy which aims to use worker's creativity by permitting them a large amount of discretion. The latter is often used with skilled and knowledge workers.

A further distinction has been drawn between detailed and general control (Edwards 1986). Even where employers do not seek direct control a set of arrangements are still required which ensures that workers are accommodated to the overall aim of the enterprise. Thus control can be exercised outside the actual performance of work tasks through the operation of internal labor markets and promotion structures.

A third feature of the employment relationship is that it is based on an asymmetry of power. The individual owner of labour power is less likely to be able to afford to be unemployed than the individual capitalist is likely to be able to refrain from employing her. This is not to suggest that there is not conflict over the terms of employment or the organisation of the labor process. The capacity of workers to resist management is based on what Wright (1979) calls their structural and organisational capacities usually expressed in trade union membership. While the state in capitalist societies depends on the flourishing of the accumulation process and seeks to induce workers (sometimes using force) to refrain from using their organisational power, it can also play a role, depending on its character, in underwriting workers rights. Indeed, Michael Burawoy (1985) has argued that the character of what he calls "factory regimes" is shaped by state intervention. He traces a shift from the despotic regimes of early capitalism to more hegemonic regimes facilitated by state intervention, through social insurance legislation and regulation of the employer/worker relationship, reducing workers' dependence on their sale of labour power. But, he claims, that with the globalisation of capital a new era of "hegemonic despotism" has emerged replacing the fear of being fired with the fear of capital flight. Combined with the emergence of neo-liberalism this has led to pressure for deregulation (Harvey 2007).

Focusing wider than the employment relationship we should note the central contradiction in capitalist societies of the gap between what technology could provide for society and what it actually does provide (Cooley 1978). In Marxist terms this refers to the contradiction between the forces and relations of production. The productive capacity of society is fettered by minority ownership and its use to enrich this minority. Thus production is not for need but to ensure capital accumulation. For Marx the logic of accumulation gives capital "no rest, and continually whispers in its ear: Go on! Go on" (Quoted in Magdoff and Foster 2011, p. 38). The motivating force of capitalism is the never-ending quest for profits and accumulation. Because of competition companies are impelled to continually increase sales and gain a bigger market share. What this means is that capitalism is always about growth. The result is production for the sake of production and the expansion of consumption to such an extent that there has been an explosion of "consumption linked to increasing wasteful lifestyles, often financed by growing household debt" (Magdoff and Foster 2011, p. 48, see also Woodhouse 2001). Despite this and the increasing global scale of capitalism the system continues to be subject to periodic crises of overproduction as it has an in-built insufficiency of demand because workers are paid less than the value of the goods they produce.

What are the implications of this approach to understanding business activity for engineers and their relations with business and management? To examine this three issues are discussed below: the place of engineers in the class structure; engineering practice in relation to safety, and the role of engineers in relation to climate change.

3.4 Engineers in the Social Structure

As part of its depth ontology CR argues that mechanisms operating at different levels can interact to shape variable social practices across different capitalist societies. An example is Chris Smith and Peter Meiksins (1995) approach, which argues for the need to investigate distinct generative processes (which they call system, society and dominance effects) to explain the strategies of firms. Examining mechanisms at different levels allows us to see how the impact of the capitalist system is mediated by national conditions. This helps us to understand why the structure and role of the engineering profession and the association between engineers and managers is divergent across similar societies. The key source of this diversity can be located in the timing and route into industrial capitalism (Lee and Smith 1992).

Whilst acknowledging this diversity, Meiksins and Smith (1996) use what they call a "structural contingency" version of Marxist theory to argue for the importance of the underlying dynamics of capitalism, as discussed above, in shaping national patterns:

> Societies may differ but this variation must be contextualized within the underlying mode of production which establishes a set of dynamic structuring relationships which establish common problems and a common set of limits within which any capitalist society must operate. (Meiksins and Smith 1996, p. 234)

By engaging with Marxist class theory they point to some commonalties across capitalist societies: the increasing complexity, technical sophistication and scale of production, and the increase in the number of educated technical workers, including engineers, who either design industrial processes and products and/or oversee or coordinate the functioning of workers or equipment used in production. Drawing on the work of Carchedi (1977) they argue that the position of engineers within enterprises is characterised by a degree of ambiguity and contradiction resulting from the structural realities of capitalism. While many are clearly workers in that they contribute their mental labour to the production process, others also contribute to the function of the 'collective worker' by coordinating increasingly complex labour processes. But they may also contribute to the 'function of capital' by performing a 'surveillance' function which involves controlling the workforce and harnessing it to the need of the valorisation process. As the capitalist enterprise grows in size and complexity we see the 'collective function of capital' being performed by managers and engineers whose work "involves varying mixes of both coordination (necessary organisation) and surveillance (managing for capital)" (Meiksins and Smith 1996, p. 15). Thus the relationships between engineers and managers, and other workers, remain somewhat open:

> engineers…may choose to define themselves as labor, manual workers may express solidarity with educated workers or may reject them; employers may, in various ways, shape organizational hierarchies so as to separate…or bring closer together these different elements of the collective laborer. (Meiksins and Smith 1996, p. 17)

The significance of this is that the position of engineers can be understood in the context of the dynamics of the labor-capital relationship. While the line between engineers and managers may not be as clear as some suggest, it does mean that some engineers are unambiguously members of management and therefore expected to make decisions which reflect their place in the managerial hierarchy (Goldman 1991). As managers they "must represent the interpretation of value judgments in relation to the interests of those on whose behalf they manage" (Holt 2001, p. 498). Their positional power as managers is held and exercised only so long as they serve the interests of those they represent. Indeed they are unlikely to achieve management status until they prove their "dependability and responsibility" and show "they can be trusted by their employers" (Beder 1998, p. 21, see also Zussman 1985; Whalley 1986). Thus it seems unrealistic, and perhaps somewhat moralistic, to expect those who have donned management hats to simply take them off.

Secondly, given the hierarchical organization of the labor process, engineers face pressures pushing them towards management and away from other workers. The use of different control strategies with different categories of workers, and provision for the exercise of responsible autonomy by engineers, may reinforce this tendency (Smith 1987). Even when engineers are performing coordination functions, others may experience this as surveillance and compulsion. So while they are part of the collective labor process, "its hierarchical nature places engineers in the ambiguous position of being part of wage labor, but linked, in various ways, to capital" (pp. 16–17). Further, given the trajectory of many engineering careers, there is pressure on engineers to conform to both bureaucratic authority and business values making them relatively indistinguishable from management (Whalley 1986). Ethnographic data collected by Kevin Anderson and others (2010) highlights how engineers work is "most significantly" constrained by "organisational business practices relating to time and budgets" (p. 169). There is a sense that the "romantic visions" that the engineers had, while at college, were knocked out of them by the "business realities of engineering" (pp. 166–167). There are strong pressures on engineers to conform to corporate agendas. These are reinforced by engineering education which, in the main, endorses a market orientated approach to education (Jamison 2013; Conlon 2008, 2013).

Thirdly, whether engineers, in contradictory locations, link with other workers to promote alternatives to the dominant business agenda may be determined by social and political factors (Smith 1987). While Hodson (2001) identifies a "general non-resistance to administrative logics" (p. 159) engineers may not always favour management especially when their integration into management hierarchies is weak. So, experiments in work humanisation in Sweden are partially explained by the strong position of trade unions with a wide membership base (including many engineers) and comprehensive legal rights at the workplace. Meiksins and Smith (1996) argue that work humanisation was facilitated because Swedish engineers were closely aligned with manual workers and were engaged in a dialogue with social scientists exposing them to the benefits of work humanisation. Similarly, in Britain, the development of the Lucas Aerospace Plan for alternative socially useful production, to replace production for the defence sector, took place in a trade union context which integrated technical and shop floor workers. Attempts to generalise the experience at Lucas were only successful when technical workers existed as an "organic resource integrated into the trade union structure at plant level" (Smith 1987, p. 44).[3] These experiments though were blocked or undermined because they either challenged managerial prerogative in the Lucas case or by the internationalisation of Swedish capital to escape the constraints' of the local environment (Bowen 2014; Meiksins and Smith 1996). In sum this points to the vulnerability of labor-centered projects in the context of a system that prioritizes some interests at the expense of others and emphasizes how engineering practice is constrained by these interests.

3.5 Safety Dilemmas

The vulnerability of labour is also exposed by even a cursory consideration of issues related to workplace health and safety. In his *magnus opus* on organisational theory Gareth Morgan says that

> each year hundreds of thousands of workers throughout the world die of work-related accidents and illnesses. Despite the major advances in occupational health and safety legislation, the issue of costs versus safety looms large on the unofficial agenda in many corporate decisions...In many situations 'the bottom line' tends to come first and safety second. (1997, pp. 302, 316, 320)

The use of a "domination metaphor" to understand organisations forces us to consider that accidents, and other adverse effects of organisations, "may all result from the way systemic forces dictate that business be done" (p. 343).

What he is doing is calling for a widening of our focus, beyond human error and individual responsibility, to understand the underlying causes of accidents. Such a focus seems to be missing from discussions of safety in engineering ethics (see Conlon 2015; Conlon and Zandvoort 2010). The dominant approach uses case studies to focus on the resolution of ethical dilemmas by individual engineers. These often involve clashes between engineers and managers and focus on the capacity of engineers to resist managerial pressures and/or engage in whistleblowing. It is assumed that not only can ethical problems be solved at the level of the individual but that engineers can act on their solutions. As a result, those using this approach

[3] In an interesting contribution to the engineering ethics literature Bowen (2014) also highlights the importance of the trade union context in supporting the development of the Plan.

tend to focus on individual failings as the key impediments to responsible action. There seems to be two problems with this approach.

Firstly, it is devoid of context.[4] As Langdon Winner (1990) says this approach to engineering ethics "tend to focus upon relatively rare, narrowly bounded crises portrayed against an otherwise happy background of business as usual… (The) contexts that underlie particular cases are never themselves called into question" (ibid., pp. 53–54). Explanations tend to ignore the analysis presented above, the way engineers become embedded in management systems and modes of decision making and how their freedom is restricted in that they typically work in "hierarchical organisations and have little room to follow their own choices" (Swierstra and Jelsma 2006, p. 314). Davis (2012) is somewhat dismissive of this idea in that he argues that engineers can break off their association with their employer at any time just by giving notice. There are many problems with this view of the employment relationship. One of them is that Davis's approach would seem to rely, to a large extent, on the heroism of individual engineers. But Hodson (2001) suggests that professional workers are least likely to engage in conflict with management. Given their considerable investment in becoming professional workers they are unlikely to jeopardize their careers by overt conflict with management. There is evidence from disaster investigations which suggests that employees were aware of problems before disasters occurred, but were either too anxious about damaging their career prospects to raise their concerns, or had raised concerns and these had been largely ignored (Agapiou 2005). Another problem is that even if the engineer breaks off their association with their employer this may not lead to change or the ending of unethical practices.

It seems that engineers are to meet their obligations to the public "regardless of any pressure they may encounter working in a corporate environment" (Lynch and Kline 2000, p. 197) or regardless of the cost of whistleblowing which can be significant (Agapiou 2005), and that individual acts of resistance can happen in a vacuum: "A solid grounding in moral philosophy, a personal moral code, and a commitment to professional responsibility are assumed to inoculate us from the weakness of will" (Lynch and Kline 2000, p. 207). The emphasis is on changing engineers rather than changing the context. By not addressing the structural context in which engineering takes place there is a danger of moralism as unrealistic expectations are placed on engineers.

Secondly, it seems to ignore much of the research on accident causation which suggests that "attempts to find an identifiable culprit (should) not obscure the more subtle causes of failure which are typically... rooted in the social and organisational properties of the overall sociotechnical system" (Pidgeon 1992, p. 18). These causes

[4] A recent systematic review, covering 21 journals in engineering educations and ethics, examining the relationship between risk management and ethics found that analysis of risk and safety is often devoid of complexity and context. It suggests that risk management is mostly used as an anecdote or an example when addressing ethics issues in engineering education. Further, it is perceived as an ethical duty or requirement, achieved through rational and technical methods. Only a small number of publications offer critical analyses of ethics education in engineering (Guntzburger et al. 2016).

recur in disparate engineering sectors. Yves Dien and others (2004) have identified recurrent features of "organisational accidents". In doing so they argue that

> the scientific community involved in the field of accident study agrees on the fact that if any event (accident, incident or crisis) is generated by direct and immediate causes ("human errors" among others), it has been induced and favoured by underlying local causes or conditions (specific technical and ergonomic conditions, local modes of personnel management, environmental characteristics, etc.) and more global organisational conditions which may be at the origin of the local conditions or have an impact on the direct or immediate causes (p. 148).

Accidents have an historical background and an unfavourable organisational context in as much as a number of decisions and unfavourable circumstances progressively generate a pre-accident situation long before the triggering of the accident itself. Accidents can be seen to have an incubation period when multiple predisposing factors accumulate. A trigger event then provokes the onset of the accident. The recurrent factors identified by Dien et al. (2004) include:

1. Weakness of the organisational safety culture;
2. Complex and inappropriate organisation;
3. Limits of operational feedback;
4. Failure of the control organisations; and
5. Production pressures.

It can be noted that many of these causes emanate from the essentially capitalist character of modern organisations entailing as they do a focus on profit and hierarchal modes of decision-making. Those using an approach based on Marxist political economy (Nichols 1997; Pearce and Tombs 1998; Tombs 2007/2008; Tombs 2010) seek to locate these causes in broader economic and political relations and the "process of capital accumulation and the relation between different classes" (Nichols 1997, p. 82). Pearce and Tombs (1998) draw explicitly on CR to argue that much work on accident causation concentrates on first-order empirical causes, such as immediate production pressures, bad communications and training, and less on second-order underlying processes which generate empirically identified first-order causes. In explaining "safety crimes" Tombs argues for an approach which places their production within "prevailing systems of economic, social and political organisation, dominant value systems and beliefs, and the differential distribution of power" (2007/2008, p. 29). He argues that there is a need to consider factors ranging from the individual through to the structural, operating at four analytically distinct levels. Individuals need to be placed in the structures in which they operate and this means taking account of their immediate work group, workplace, company and the wider environment in which the company operates. This leads to a focus on the relationship between profit and safety, management and workers, the role of the state in regulating safety and supporting a "voice" for workers and state business relations. In this context the advent of neo-liberal regimes with commitments to deregulation and the valorisation of risk have had a detrimental effect on workplace safety. What is significant about this approach is that it seeks to integrate mechanisms operating at different levels into explanations of management and worker interactions and their effects on safety. It focuses on the distribution of power and

> exposes as socially specific what is taken for granted, revealing how what is, was not always so, and need not necessarily be, with existent states of affairs only comprehensible in the context of macro-level social processes, on both national and international levels. (2007/2008 p. 30)

This approach does not argue that there is always a conflict between safety and profits. There may be a coincidence of interest between accumulation and safety, whereby improvement in safety may go hand in hand with improvement in profit, particularly when a major disaster or a record of consistent accidents and injuries may disrupt the production process or make it hard to recruit employees. Further, some companies engage in long-term calculations of profitability and are more likely to provide safer workplaces (Nichols 1997; Pearce and Tombs 1998). Notwithstanding this, Pearce and Tombs argue that it would be "ludicrous to ignore the dynamic tendency to accumulate within a capitalist society since this provides the *raison d'etre* of the private corporation". They say there is an ultimate and inevitable truth to the argument that profit maximisation is the most fundamental cause of accidents – "it is accurate in the last instance". But they are keen to avoid the implication that accidents are therefore inevitable. There is a danger that posing a mutual exclusivity between safety and profits leads to political passivity as accumulation takes precedence over all other goals and reforms are rendered unlikely. They argue for the need to develop an appreciation of how the drive for accumulation is articulated with second-order causes and counter-tendencies to accidents and thereby consider how they might be prevented (1998, pp. 134–135). Therefore a greater degree of equality in workplace relations is required if "distorted communication" is to be overcome: "it is often workers themselves (including engineers) who first and accurately recognise the dangers associated with particular production processes only to have this recognition ignored" (p. 144).

In this context the roles of regulation and worker participation in organisational decision making assume significance. Some approaches to engineering ethics have focused on specific changes in structures of corporate and management accountability including holding senior executives responsible for accidents and deaths and for strict penalties, including imprisonment, when their organisation is found guilty (De George 1981). Henk Zandvoort (2005) has proposed wide ranging changes to legal systems to enable socially responsible behavior in engineering and the promotion of sustainability, including a regime of strict liability. He also argues for changes to the laws governing responsibility in organisations and proposes that organisations operate on the basis of 'shares of responsibility' for their activities. Underlying this work is the recognition that "If the engineers' claims for safety have to survive in a context dominated by competition for money and power, regulation with an ethical content may be the engineers life jacket" (Coeckelbergh 2006). But given the role of the state in encouraging capital growth and mobility we must be circumspect about the stability of regulatory gains and the possibility of them being swept away by policies aimed at altering the balance of class relations such as those emanating from the current neo-liberal consensus. Thus there is an onus on us to consider "alternative means of organising production regimes that will neither encourage nor sustain the routine killings, injuries, disease and widespread emiseration of lives wreaked by corporations" (Tombs 2010, p. 899).

3.6 Climate Dilemmas

This issue also arises for engineers in the context efforts to address the challenge of climate change. According to Jowitt (2010) one of the tasks, of truly global proportions, confronting engineers in the twenty-first century is engineering the world to avert an environmental crisis in terms of energy use, greenhouse gas emissions and their contribution to climate change. While engineers are encouraged to promote and practice the principles of sustainable development most of the focus in engineering is on evaluating technical reliability and environmental impact (Lucena et al. 2010).

For Marx there is a fundamental contradiction between nature and capitalism: "Capitalist production...develops technology, and the combining together of various processes into a social whole, only by sapping the original sources of all wealth – the soil and the labourer" (Quoted in Burkett 2005), p. 80). Marxists would argue that there is a rapidly intensifying contradiction between capitalist relations of production and the survival of human and other species (Magdoof and Foster 2011). This contradiction between the needs of the economic system and the requirement of sustainability may undermine the efforts of engineers in delivering a sustainable future. For engineers a key question is whether "technical change can reduce the impact of economic development sufficiently to ensure other changes will not be necessary" (Beder 1998, p.198). There is evidence to suggest otherwise.

In its Fifth Assessment Report the International Panel on Climate Change (IPCC) showed that total Greenhouse Gas Emissions increased between 1970 and 2010, with larger absolute increases between 2000 and 2010, despite a growing number of climate change mitigation policies. While globally, economic and population growth continued to be the most important drivers of increases in CO2 emissions the IPCC goes on to say: "The contribution of economic growth has risen sharply" (IPCC 2014, p. 5).

In order to test the feasibility of the European Union (EU) meeting its targets for 2020, Finish researchers analyzed carbon dioxide emissions between 1993 and 2004. Although emissions in the entire Union grew only by an average of 0.31% per year, emissions and their drivers varied markedly among the 27 member states. Dematerialization and de-carbonization did occur, but not enough to offset the slight population growth plus rapidly increasing affluence. In order to fulfill its obligation to 2020 the EU27 will have to counter its increasing population and affluence by a combined dematerialization and de-carbonization 1.9–2.6 times faster than during 1993–2004 (Saikku et al. 2008). Ireland faced a particular difficult task as the strongest upward drivers were changes in population (1.2%/year) and, most importantly, affluence (6.9% per year) again undermining the de-carbonization that had occurred.

Therefore, it is unsurprising to learn that Ireland was only able to meet its commitments under the Kyoto Protocol due to the great recession, which began in 2008, and which led to an almost complete collapse of the economy. According to the Environmental Protection Agency (2013): "Whilst the reduction in the distance to target for the Kyoto Protocol period is a positive outcome in terms of compliance, its occurrence is, primarily, a direct result of the current economic recession and economic outlook for the future."

There are two other issues that should be highlighted in relation to emissions. Firstly, emission reductions in developed countries often result from the export of emissions. Data for 2014, provided by the Tyndall Centre for Climate Change Research, shows that while the EU had decreased its emissions by 1.8% it continued to export a third of its emissions to China and other producers through imported goods and services (Tyndall Centre 2014). The accounting of these emissions is problematic in that current methods tend to focus on production related emissions. A focus on the final point of consumption would show very different trends in emissions, particularly in developed countries. Helm et al.'s (2007) analysis of Britain's emissions shows that rather than a 2.1% per annum decrease since 1990, a consumption related inventory approach, which include emissions embedded in imports, shows that emission have actually increased by 19%.

This trend to offshore emissions is a direct result of investment and profit seeking activities of major corporations (Malm 2016).[5] Andreas Malm, using a Marxist framework, presents some stark facts to show how China's full integration into the global economy, following its membership of the World Trade Organization in 2001 and the dismantling of barriers to foreign investment, led to an explosion of emissions. While investment decisions were driven by the availability of compliant and cheap labor, with costs less than 5% those of the US or the EU, the growth in emissions was due to Chinas high carbon intensity. As much as 48% of its emissions between 2002 and 2008 were generated in the export sector which is dominated by foreign companies (FIEs) (ibid., p. 339). He concludes that "Given the role of FIEs in Chinese exports, and that of exports in Chinese emissions, we may thus infer that the quest for maximum surplus-value was indeed a paramount mechanism for igniting the explosion" (Ibid., p. 342).

Secondly, emissions result mainly from the activities of a relatively small but well off group of people. Work by Stephen Pacala (2007), Director of the Princeton Environmental Institute, shows that the top 500 million emitters are responsible for half of the world's greenhouse emissions. Because of the tight correlation between income and emissions, the top 500 million emitters are also the 500 million richest people. Two-thirds live in developed countries, but fully one-third live in developing countries. In contrast, the 3.1 billion poorest and lowest emitting people (the bottom half of the global distribution) are responsible for only 5–10% of the world's emis-

[5] This should caution us against simply blaming consumers in the developed world for the growth in emissions. Indeed, it is often workers in the richer countries who are the most vigorous opponents of offshoring jobs to havens of cheap labor (and high emissions). It should also make us sceptical about corporate claims to be going green.

sions. Given this it is not surprising that "mitigation and adaptation raise issues of equity, justice, and fairness. Many of those most vulnerable to climate change have contributed and contribute little to GHG emissions" (IPCC 2014, p. 17).

It seems then that the work of many engineers in generating technological efficiencies are being undermined by economic growth. This is unsurprising given what is known as Jevons' Paradox, after William Stanley Jevons who, following his study of the use of British Coal in the 1800s, argued that the increased efficiency of coal would not lead to a diminished demand for it (Foster et al. 2010). John Bellamy Foster and others (2010) argue, as Marxists, for its use in understanding current trends and that improvements in energy efficiency can lower the effective cost of various products, propelling the overall economy and expanding overall energy use. They argue that much analyses of the Jevons Paradox have remained abstract and based on isolated technological effects. Its impact has to be understood at the macro level and in the context of capitalism as a system which will tend to use any efficiency gains to expand the overall scale of production. Pessimistically they conclude, based on historical evidence which Huesemann (2003, p. 30) summarises as telling us that "technological innovation has never been used to stabilize the size of the economy; in fact quite the opposite, namely the enhancement of industrial productivity, consumption and economic growth", that "conservation in the aggregate is impossible for capitalism, however much the output/input ratio may be increased in the engineering of a given product" (Ibid., p. 10). While I am not addressing the issue of the transition to an energy system based on renewables here,[6] it can be noted that the global record for the period from 1960 to 2009 is that 1 kwh of renewable electricity replaces an average of 0.1 kwh of fossil electricity (York 2012). Rather than replace fossil fuels, renewable have added to an ever-growing energy pie leaving them to compete in an energy market driven by supply and demand.: "If solar and wind were to become radically cheaper than fossil fuels, demand for the later might fall – only to induce a corresponding fall in their prices, reviving demand and establishing an equilibrium of profligacy" (Malm 2016, p. 382).

It seems useful then to locate the pattern of emission increases in the operation of the global economic system, its thirst for growth and profit and the pattern of class relations. Viewing the problem in national terms seems unhelpful, given that it is rich people across the globe who are benefiting most from increased growth and contributing to a climate crisis which will impact most on those who have least. Klein (2014) argues that neo-liberal policies that privilege elites and free corporations from constraints are those that have contributed most to rising emissions. Summarising data from a range of sources she says:

[6] See Malm (2016, Chap. 15) for an excellent analysis. He highlights the manner in which the transition is fettered by capitalist relations of production and the withdrawal from investment in wind and solar by major corporations due to low levels of profitability: "capital did not engage in the transition as many had expects it would, largely *because energy from the flow (wind and solar) lost so much of its exchange-value* at the very same time that its social use-value –slowing down climate change- rose towards priceless heights" (p. 371 emphasis in original).

> The numbers are striking: in the 1990s, as the market integration project ramped up, global emissions were going up an average of 1 per cent per year; by the 2000s, with emerging markets like China now fully integrated into the world economy, emissions growth had sped up disastrously, with the annual rate of increase reaching 3.4 percent for much of the decade. The rapid growth continues to this day, interrupted only briefly in 2009 by the world financial crises. (2014, p. 20)

Ominously in 2010 they increased by nearly 6%: the largest absolute increase since the Industrial Revolution (p. 18). Such trends have led to some leading climate scientists, such as Kevin Anderson at the Tyndall Centre, described by Klein as "spikey-haired former mechanical engineer" (2014, p. 87), to argue that the kinds of cuts needed cannot be achieved without immediate degrowth strategies (Anderson and Bows-Larkin 2010; Anderson 2013). He claims that wealthier nations need to reduce their emissions by between 8% and 10% per annum but that he can find no examples, despite lengthy literature searches, of economists suggesting that prolonged emission reductions above 3–4% are economically sustainable.

The demand for degrowth is not unproblematic. Some working in a Marxist framework have rightly posed the question as to whether degrowth is achievable without fundamentally changing the nature of our economic system. The levels of degrowth required could be such as to impoverish large sections of the population through escalating levels of unemployment. Minqi Li (2008) has examined various scenarios for emissions reductions by examining the interaction of reductions in emission and energy intensity and economic growth consistent with a target of keeping global warming below 2°. He concludes, even where the declines in emissions and energy intensity are optimistic in comparison with the historical record that the world economy would have to fall by two-thirds to three quarters to 2050 to keep warming below 2°. Fred Magdoof and John Bellamy Foster (2011) have examined the post war relationship between growth and unemployment in the USA and conclude that only in the 13 years when growth was in excess of 5% did unemployment not increase at all.

What is suggested here is that we need to move beyond the social, economic and power relations of capitalism. Degrowth can only take on genuine meaning as part of a critique of capital accumulation as it violates the basic motive force of capitalism. We "must aim not merely for degrowth in the abstract but... a transition away from a system geared to the accumulation of capital without end" to one that meets "the common needs of humanity and the earth" (Foster 2011).

What this means in practice, for engineers and others, may be gleamed from a journal closer to the engineering domain. In a Special Issue on degrowth the Journal of Cleaner Production carries contributions from the Second International Conference on Degrowth and seems to suggest that some of those arguing for degrowth are cognisant of the need to alter current economic relations and practices. In its editorial (Sekilova et al. 2013) we discover that degrowth entails a downscaling of "the role of markets and commercial exchanges as a central organising principle of human lives"; "rethinking needs and shifting objectives away from the regime of accumulation in monetary terms"; "setting binding macro level constraints" and not just relying on "simple individual action"; and "institutional changes starting with the abandonment of the corporate structure as a form of productive organisation". These actions might set us an a path towards Marx's "Vision of Sustainable Human Development" in a society "organised for cooperative working on a planned basis...to ensure all members of society the means of existence and the full development of their capacities" (Quoted in Burkett 2005, p. 5).

3.7 Conclusion

The analysis presented here suggests there are significant constraints on engineering practice, emanating from the corporate environment, which affect engineers capacities to hold paramount the health, safety and welfare of the public. The central contradiction of capitalism, between the forces and relations of production, ensures that the potential in engineering to further human welfare and protect the environment will always be fettered by capitalist relations of production. The structural location of engineers within corporations creates pressure for conformity with managerial agendas. In contrast to some who have argued for the captivity of engineering (e.g. Noble 1977) the approach adopted here is not deterministic in that there is scope, within the constraints of the system, and given its many contradictions, which invariably leads to resistance, to further agendas which may not always be in the interest of corporations. But engineers cannot, and will not, be able to further such agendas by themselves. A key insight of Science and Technology Studies is that technology and society are co-determined: engineers do not just produce technology, but socio-technical systems which shape human activity (Johnson and Wetmore 2007). Thus engineers must engage with other actors who are responsible for the development of socio-technical systems. It is also possible that through alliances with other workers engineers can further demands for democratic reform of work, share technical and production knowledge and "struggle against the waste of people, resources and the environment that capitalism produces" (Meiksins and Smith 1996, p. 382).

In the language of CR there are countervailing mechanisms at work: the social structure conditions but does not determine leaving scope for change. Archer (1995) has argued for the importance of historical time in understanding agency/structure relations. While structures predate agency and are dependent on activity, those actions that produce a given structure may be those of a past generation. Once these differential temporalities of structure and agency are taken into account it becomes necessary to differentiate the two and examine their interplay. In order to do so, Archer (1995) has proposed her *morphogenetic* model of explanation which works on the basis of a three part cycle of analysis:

(a) Structural conditioning: pre-existence structures as generative mechanisms that condition but do not determine;
(b) Social interaction: their interplay with other objects including agents possessing causal powers leading to

(c) Structural elaboration or modification: non-predictable but explicable outcomes arising from the interactions between the above.

The model allows us to focus on the interplay between structure and agency and the possibility of change arising from social interactions over time: "social interaction elaborates upon the composition of the social structure(s) by modifying…structural relationships and introducing new ones where *morphogenesis* is concerned". Alternatively, it may lead to *morphostasis* when structural relations are simply reproduced (ibid., p. 169). In William Lynch's recent contribution to engineering ethics he states that: "it is possible that a larger systematic change to established practices over a longer period of time may have a greater chance of being effective than pinning one's hope on heroic intervention at the last moment" (Lynch 2015). In effect he is arguing for a shift from a focus on individual engineers to the structural conditioning of their practice over time.

The challenge to established practices must involve a challenge to the dominance of corporations as a key factor conditioning the practice of engineering. Changing it involves interventions, by engineers and others, in the public policy domain to regulate and ultimately change current practices. Thus we need to examine the kinds of project engineers pursue and how their interventions contribute to the *structural conditioning* of engineering practice into the future. Therefore CR provides a basis for placing second order responsibilities on engineers to strive for the creation of supportive social environments which enable their social responsibility (Conlon 2015). This requires us to abandon value neutrality and identify the features of the social structure which need to change in order to facilitate engineering practices which promote safety, sustainability and social justice. It also involves a commitment to engineering activism, engagement with anti-corporate actors such as social movements and trade unions and inevitably an engineering politics (Karwat et al. 2015; Mitcham and Nan 2015). In this context there is a responsibility on those educating engineers to provide students with a sense that change is necessary and possible and that there are alternatives to market based systems which constrain the activities of engineers. Without a sense that there are alternatives agency fails to have any real meaning as outcomes are predetermined.

References

Agapiou, A. (2005). Whistle-blowing protection provisions for construction industry employees. *Construction Information Quarterly, 7*(4), 135–141.

Anderson, K. (2013). *Avoiding dangerous climate change demands de-growth strategies from wealthier nations*. Available at: http://kevinanderson.info/blog. Accessed 01-06-16.

Anderson, K., & Bows-Larkin, A. (2010). Beyond 'Dangerous' climate change: Emission scenarios for a New World. *Philosphical Transactions of the Royal Society A, 369*, 20–44.

Anderson, K., Boyett, J., et al. (2010). Understanding engineering work and identity: A cross-case analysis of engineers within six firms. *Engineering Studies, 2*(3), 153–174.

Archer, M. (1995). *Realist social theory*. Cambridge University Press.

Beder, S. (1998). *The new engineer*. Sydney: Macmillan.

Benton, T., & Craib, I. (2011). *Philosophy of social science* (2nd ed.). Basingstoke: Palgrave.

Bowen, W. R. (2014). *Engineering ethics: Challenges and opportunities*. London: Springer.

Braverman, H. (1974). *Labour and monopoly capitalism*. New York: Monthly Review Press.

Brown, R. K. (1998). The employment relationship in sociological theory. In D. Gaille (Ed.), *Employment in Britain*. Oxford: Basil Blackwell.

Burkett, P. (2005). Marx's vision of sustainable human development. *Monthly Review, 57*(5), 34–62 Available at: http://monthlyreview.org/2005/10/01. Accessed 01-02-15.

Burowoy, M. (1985). *The politics of production*. London: Verso.

Carchedi, G. (1977). *On the economic identification of social classes*. London: Routledge.

Carter, B., & New, C. (2004). *Making realism work*. Abingdon: Routledge.

Coeckelbergh, M. (2006). Regulation or responsibility? Autonomy, moral imagination and engineering. *Science, Technology & Human Values, 31*(3), 237–260.

Collier, A. (1994). *Critical realism*. London: Verso.

Conlon, E. (2008). The new engineer: Between employability and social responsibility. *European Journal of Engineering Education, 33*(2), 151–159.

Conlon, E. (2013). Broadening engineering education: Bringing the community in. *Science and Engineering Ethics, 19*(4), 1589–1594.

Conlon, E. (2015). A critical realist approach to engineering ethics. *IEEE International Symposium on Technology and Society (ISTAS*). Dublin, November 2015.

Conlon, E., & Zandvoort, H. (2010). Broadening ethics teaching in engineering: Beyond the individualistic approach. *Science and Engineering Ethics, 17*(2), 217–232.

Cooley, M. (1978). Design, technology and production for social needs. In K. Coates (Ed.), *The right to useful work*. Nottingham: Spokesman.

Craib, I. (1992). *Modern social theory* (2nd ed.). New York: St. Martin's Press.

Danermark, B., Ekström, M., Liselotte Jakobsen, L., & Karlsson, J. C. (2002). *Explaining society. Critical realism in the social sciences*. London/New York: Routledge.

Davis, M. (2012). "Ain't no one here but us social forces": Constructing the professional responsibility of engineers. *Science and Engineering Ethics, 18*(1), 13–34.

De George, R. T. (1981). Ethical responsibilities of engineers in large organizations: The Pinto case. *Business & Professional Ethics Journal, 1*(1), 1–14.

Dien, Y., Llory, M., & Montmayeul, R. (2004). Organisational accidents investigation methodology and lessons learned. *Journal of Hazardous Materials, 111*(1–3), 147–153.

Edwards, P. (1986). *Conflict at work*. Oxford: Blackwell.

Environmental Protection Agency. (2013). *Ireland's greenhouse gas emission projections 2012–2030*. Dublin: EPA.

Foster, J. B. (2011). Capitalism and degrowth: An impossibility theorem. *Monthly Review, 62*(8), 26–33 Available at: http://monthlyreview.org/2011/01/01. Accessed 05-04-2016.

Foster, J. B., Clark, B., & York, R. (2010). Capitalism and the curse of energy efficiency: The return of Jevons paradox. *Monthly Review*, *62* (6). Available at: http://monthlyreview.org/2010/11/01. Accessed 05-04-2016.

Friedman, A. L. (1977). *Industry and labour*. Basingtonstoke: Lacmillan.

Goldman, S. L. (1991). The social captivity of engineering. In P. T. Durbin (Ed.), *Critical perspectives on non-academic science and engineering*. Bethlehem: Lehigh University Press.

Guntzburger, Y., Thierry, C., Pauchant, T. C., & Tanguy, P. A. (2016). Ethical risk management education in engineering: A systematic review. *Science and Engineering Ethics.* First Online. Available at: http://link.springer.com/article/10.1007/s11948-016-9777-y. Accessed 01-05-2016.

Harvey, D. (2007). *A brief history of neo-liberalism*. Oxford University Press.

Helm, D., Smale, R., & Phillips, J. (2007). *Too good to be true? The UK's climate change record.* Available at: http://www.dieterhelm.co.uk/publications/Carbon_record_2007.pdf. Accessed 01-06-2015.

Hodson, R. (2001). *Dignity at work*. Cambridge University Press.

Holt, J. E. (2001). The status of engineering in the age of technology. *International Journal of Engineering Education, 17*(6), 496–501.

Huesemann, M. H. (2003). The limits of technological solutions to sustainable development. *Clean Technologies and Environmental Policy, 5*, 21–34.
Hyman, R. (1987). Strategy or structure: Capital, labour and control. *Work, Employment and Society, 1*(1), 25–55.
Hyman, R. (2006). Marxist thought and the analysis of work. In M. Korczynski, R. Hodson, & P. Edwards (Eds.), *Social theory at work*. Oxford: Oxford University Press.
IPCC. (2014). *Climate change 2014: Synthesis report. Fifth assessment report of the intergovernmental panel on climate change*. Geneva: IPCC.
Jamison, A. (2013). *The making of green engineers*. San Rafael: Morgan and Claypool.
Johnson, D. G., & Wetmore, J. M. (2007). *STS and ethics: Implications for engineering ethics. The handbook of science and technology studies*. MIT Press.
Jowitt, P. (2010). Engineering, innovation, social and economic development. In *Engineering: Issues, challenges and opportunities for development*. UNESCO.
Karwat, D. M. A., Eagle, W. E., Wooldridge, M. S., & Princent, T. E. (2015). Activist engineering: Changing engineering practice by deploying practice. *Science and Engineering Ethics, 21*(1), 227–239.
Klein, N. (2014). *This changes everything: Capitalism vs the climate*. London: Allen Lane.
Korczynski, M., Hodson, R., & Edwards, P. (2006). *Introduction to Social theory at work.* Oxford University Press.
Kotta, L. (2011). Engineering education, practice and engineering research: Critical realist insights. *Proceedings of the AAEE Conference, 5*(2011), 19–29.
Lee, G. L., & Smith, C. (1992). *Engineers and management*. London/New York: Routledge.
Li, M. (2008). Climate change, limits to growth, and the imperative for socialism. *Monthly Review*, 60 (3). Available at: http://monthlyreview.org/2008/07/01. Accessed 05-04-2016.
Lucena, J., Schneider, J., & Leydens, J. A. (2010). *Engineering and sustainable community development*. San Rafael: Morgan and Claypool.
Lynch, W. (2015). Second guessing scientist and engineers: Post hoc criticism and the reform of practice in green engineering. *Science and Engineering Ethics, 21*(5), 1217–1240.
Lynch, W. T., & Kline, R. (2000). Engineering practice and engineering ethics. *Science, Technology & Human Values, 25*(2), 195–225.
MacKenzie, D. (1996). *Knowing machines*. Cambridge, MA: MIT Press.
Magdoff, F., & Foster, J. B. (2011). *What every environmentalist needs to know about capitalism*. New York: Monthly Review Press.
Malm, A. (2016). *Fossil capital*. London/New York: Verso.
Marx, K. (1954). *The eighteenth Brumaire of Louis Bonaparte*. Moscow: Foreign Languages Pub. House.
Meiksins, P., & Smith, C. (1996). *Engineering labour*. London/New York: Verso.
Mitcham, C., & Nan, W. (2015). From engineering ethics to engineering politics. In S. H. Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, & B. Newberry (Eds.), *Engineering identities, epistemologies and values, engineering education and practice in context* (Vol. 2). Dordrecht: Springer.
Morgan, G. (1997). *Images of organisations*. Thousand Oaks: Sage.
Nichols, T. (1997). *The sociology of industrial injury*. London: Mansell.
Noble, D. (1977). *America by design*. Oxford: Oxford University Press.
Pacala, S. (2007). *Equitable solutions to greenhouse warming: On the distribution of wealth, emissions and responsibility within emissions and responsibility within and between nations.* Lecture to International Institute for Applied Sytem Analysis, November 2007. Available at: http://www.precaution.org/lib/pacala_wealth_and_gw.090601.pdf. Accessed 01-06-2015.
Pearce, F., & Tombs, S. (1998). *Toxic capitalism*. Dartmouth: Ashgate.
Pidgeon, N. (1992). The psychology of risk. In D. Blockley (Ed.), *Engineering safety*. Maidenhead: Mc Graw Hill.
Porpora, D. V. (1998). Four conceptions of social structure. In M. Archer, R. Bhasker, et al. (Eds.), *Critical realism: Essential readings*. London/New York: Routledge.

Reed, M. (2005). The agency/structure dilemma in organization theory: Open doors and brick walls. In C. Knudsen & H. Tsoukas (Eds.), *The Oxford handbook of organization theory.* Oxford University Press.
Saikku, L., Rautiainen, A., & Kauppi, P. E. (2008). The sustainability challenge of meeting carbon dioxide targets in Europe by 2020. *Energy Policy, 36*(2), 730–742.
Scott, D. (2000). *Realism and educational research: New perspectives and possibilities*. London: Routledge.
Seiklova, F., Kallis, G., et al. (2013). Degrowth: From theory to practice. *Journal of Cleaner Production, 38*, 1–6.
Smith, C. (1987). *Technical workers, class, labour and trade unionism*. London: Macmillan.
Smith, C., & Meiksins, P. (1995). System, society and dominance effects in cross-national organisational analysis. *Work, Employment and Society, 9*(2), 241–267.
Swierstra, T., & Jelsma, J. (2006). Responsibility without moralism in technoscientific design practice. *Science, Technology & Human Values, 31*(3), 309–332.
Thompson, T., & Mc Hugh, D. (2002). *Work organisations* (3rd ed.). Basingstoke: Palgrave.
Tombs, S. (2007/8). A political economy of corporate killing. *Criminal Justice Matters, 70*(1), 29–30.
Tombs, S. (2010). Corporate violence. In F. Brookman, H. Pierpoint, T. Bennett, & M. Maguire (Eds.), *Handbook on crime* (pp. 884–903). Cullompton: Willan.
Tyndall Centre. (2014). *CO2 emissions set to reach new 40 billion tonne record high in 2014.* Available at: http://www.tyndall.ac.uk/communication/news-archive/2014. Accessed 01-06-2015.
Whalley, P. (1986). *The social production of technical work*. Basingstoke: Macmillan.
Winner, L. (1990). Engineering ethics and political imagination. In P. Durbin (Ed.), *Broad and narrow interpretations of philosophy of technology: Philosophy and technology* (Vol. 7). Boston: Kluwer.
Woodhouse, E. J. (2001). Curbing overconsumption: Challenge for ethically responsible engineering. *IEEE Technology and Society Magazine*, Fall 2001, 23–30.
Wright, E. O. (1979). *Class, crises and the state*. London: Verso.
York, R. (2012). Do alternative energy sources displace fossil fuels? *Nature Climate Change, 2*, 441–443.
Zandvoort, H. (2005). Good engineers need good laws. *European Journal of Engineering Education, 30*(1), 21–36.
Zussman, R. (1985). *Mechanics of the middle class*. Berkeley: University of California Press.

Eddie Conlon Lecturer (Structured) in School of Multidisciplinary Technology at Dublin Institute of Technology. He holds a Masters in Sociology from University College Dublin. He is generally interested in the sociology of work but in recent years has published work on engineering ethics and the integration of sustainability in engineering education. He teaches modules focused on engineering and society. He is the coordinator of a general entry programme for engineering technologists in the College of Engineering & Built Environment at DIT.

Chapter 4
Actualization of the Professional Ideal of Engineers in Québec: A Review of a Few Obstacles

Luc Bégin, A. Lacroix, L. Langlois, and D. Rondeau

Abstract With mandates from *L'Ordre des ingénieurs du Québec* and with the collaboration of a public organization employing a few hundred engineers, we were able to document important areas of tension between the professional ideal of engineers and the obligations imposed by the workplace context, in public as well as in private markets. This was particularly the case of engineers that were salaried employees. The tension between market logic and professional logic in these working environments reflects certain problematic aspects concerning the actualization of the professional ideal of engineers. Based on data gathered under these mandates and on the literature of organizational as well as professional ethics, we will first be concerned with the subject of multiple loyalties and the challenges it represents for the salaried engineer considering the actualization of his professional ideal. We will secondly consider two aspects of another phenomenon that obstructs this actualization: the phenomenon of de-professionalization. And finally, we will conclude by exploring certain ways to counter the damaging effects of these obstacles.

This publication profited from the support of the FRQ-SC (*Fonds de recherche Société et Culture du Québec*), under a grant from the *Soutien aux équipes de recherche* on the subject of «*Institutionnalisation et intervention en éthique*».

L. Bégin (✉)
Faculté de philosophie, Université Laval, Québec, Québec, Canada
e-mail: luc.begin@fp.ulaval.ca

A. Lacroix
Département de philosophie et d'éthique appliquée, Université de Sherbrooke, Longueuil, Québec, Canada
e-mail: Andre.lacroix@usherbrooke.ca

L. Langlois
Département de relations industrielles, Université Laval, Québec, Québec, Canada
e-mail: Lyse.Langlois@rlt.ulaval.ca

D. Rondeau
Département des lettres et humanités, Université du Québec à Rimouski, Québec, Canada
e-mail: dany_rondeau@uqar.ca

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_4

Keywords Ethics · Engineers · Professional ideal · Multiple loyalties · De-professionalization process

4.1 Introduction

Like many other professions, engineering's practice settings will follow the developments of market economy and of transformations in the workplace. One of the most significant consequences will be the rise in the number of engineers that are wage employees within organizations where they often have to relate to a wide range of professionals from different fields. As employees of sometimes very large organizations – public services, engineering consulting firms, aerospace companies, etc. – their professional activities must take into account structures that aim, in a market logic, at the highest possible benefits. This does not go without creating pressure on the engineers' professional practices. Therefore, certain conditions in the actualization of their professional ideal will be inevitably affected by these developments and transformations. In numerous situations where engineers are wage employees, we have observed obstacles in actualizing their ideal. This is at least the assumption that we intend to document and support in this chapter.

Our analysis is based on data gathered in Québec, where the engineering profession has been at the center of certain current and public issues, to which we shall return in the first section of the chapter. One must also take into account that the Québec's context of regulation of the engineering profession is something rather singular and that this certainly has an effect on how the professional ideal of engineers is conceived and actualized. There is no doubt that this context, on which we will briefly focus in our first section, will guide our analysis and the conclusions that we will put forward. Nonetheless, we have good reason to believe that a fair number of our explanatory hypotheses of these obstacles to the actualization of the engineers' professional ideal are likely to be relevant and to clarify significantly similar phenomena in different cultural and legal contexts. Furthermore, since our contribution will specifically apply to the situation of engineers that are wage employees, we will insist on the relevance of using analytical frameworks that originate from organizational as well as professional ethics. The first section of the chapter will thus set up essential elements to the comprehension of our subsequent developments: (1) Québec's context of regulation of the engineering profession; (2) the context by which our database was produced for our analysis; (3) the analytical frameworks that were mobilized.

In the second section, we will consider the first of the two phenomena that seem problematic concerning the actualization of the engineers' professional ideal: the case of multiple loyalties. The situation of the salaried engineer within an organization is objectively one of multiple loyalties. At the same time an employee and a professional, the salaried engineer finds herself/himself at the intersection of two courses of action not always compatible, therefore putting him in a situation of conflict of loyalties. We shall document this question of loyalties so as to show how the actualization of the professional ideal is compromised. As her/his status as an employee is confronted with an inversion of the asymmetry of power that normally characterizes the professional activity, the salaried engineer finds herself/himself in a position of vulnerability that can possibly lead him to give up the actualization of the constituent values of his professional ideal.

In the third section, we shall consider another phenomenon that can be an obstacle to the professional ideal: the de-professionalization process. In certain working contexts in an organization, the de-professionalization process takes two forms that we shall distinguish, although they can very often be complementary. On the one hand, the de-professionalization process is to be understood as a decrease in the exercise of an autonomous professional judgment. On the other hand, we shall rather refer to it as a weakening of the engineer's professional identity. In both cases, the de-professionalization process results in working practices disconnected from the ideals and the values of the profession.

Finally, in our conclusion we shall present some lines of thought in developing strategies to counter the most noxious effects of these obstacles to the actualization of the engineer's professional ideal.

4.2 Elements of Context

The practice of engineering in Quebec is inserted in a legal, statutory and ethical frame, created and imposed by Québec's own professional system, a structure set up by the legislator at the beginning of the 1970s.[1] Presently more than 40 professions are governed by the *Code des professions*, which is the essential legal source of this professional system. As for all other professions recognized by the Québec legislator, the profession of an engineer is controlled by a professional order – *L'Ordre des ingénieurs du Québec* (OIQ) – which is accountable to the *Office des professions*. The latter is the body responsible for the enforcement of the *Code des professions* but also for the entire legal frame of the professional system, and more widely of all the legal supervision of Québec's professional system. All the engineers practicing in Québec in the one or the other engineering specialties recognized in the *Code des professions* are necessarily members of the OIQ, otherwise at risk of being the object of legal pursuits.

Every engineer working in Québec has to follow a set of legal and statutory requirements among which the Professional Code, the Engineers Act and the Code of ethics of engineers, stipulating duties and obligations to be respected, particularly in relation to the public, the customer, and the profession. It is important to know that *L'Ordre des ingénieurs du Québec* has as its principal mission to watch over the protection of the public. Unlike the former professional corporations that defended the profession's special interests and its members, the professional orders have presently to make sure that their members' practices conform to a set of standards that

[1] One will find a presentation of the reasons leading the Québec legislator to adopt this system in Legault (1999, pp. 7–38).

must guarantee the public's protection. Consequently, the orders have then to set up structures, from professional inspection to mechanisms of investigation and discipline. The guilty professionals expose themselves to disciplinary measures going from the simple reprimand to fines and, in the most severe cases, to the exclusion from the order, which involves losing the right to practice. Besides, these measures do not exempt the professional from criminal and civil prosecution by parties possibly affected by his actions.

This raises the question of what happens regarding the professional ideal of the engineers in a strongly formalized professional system that is, in addition, imposed by the Québec legislator. It is necessary to know that the duties and obligations listed in the Code of ethics of engineers do not express the entire ethos of the profession. While the Code insists on obligations concerning, in particular, public safety, integrity, professional autonomy, availability and professional secrecy, *L'Ordre des ingénieurs du Québec* also reminds engineers that their professional ideal advocates four very important values that must guide them in their professional practice: competence, sense of the ethics (in reference to the professional conscience and to the duty of favoring first and foremost the interest of society as well as customers), responsibility and social commitment. Thus, the professional ideal of the engineers does not rely solely on obligations imposed upon them but also calls on values that must establish their professional identity and guide them positively in their choices and actions on a daily basis.

The difficulties actualizing this ideal were particularly clear during a series of unfortunate events involving engineers that occurred in Quebec between 2006 and 2015. These events brought the profession into headline news. The authors produced the data for analysis following these events when asked to participate in various initiatives with the objective of shedding light on certain aspects surrounding them. The first event arose in 2006 when an overpass collapsed – the Boulevard de la Concorde overpass – which spans an expressway in the north suburb of Montreal. This incident caused the death of five passengers in two motor vehicles, crushed by the falling overpass, and also injured six other people. A Commission of inquiry, also known as The Johnson Commission (after its chair Pierre-Marc Johnson) was established to investigate the circumstances of the collapse, determine the causes, and formulate recommendations to avoid that such a tragedy should be repeated. Following its release, the OIQ appointed the co-researchers Bégin and Rondeau to proceed with an analysis of the Commission's report so as to provide, from an ethical point of view, considerations susceptible to direct the reflections and the actions of the OIQ. We also had the mandate of proposing hypotheses that could result in a subsequent and extensive research. As we will show, certain analyses made in our report highlight obstacles to the actualization of the engineers' professional ideal (Bégin et al. 2009).

The second source of information stems from a private survey conducted for the benefit of the *L'Ordre des ingénieurs du Québec* in 2011 and for which the co-researchers Bégin and Lacroix had the opportunity to participate as expert advisors in ethics.[2] During several months, Québec's media had revealed disturbing information about the illegal financing of political parties, embezzlements, corruption and collusion in obtaining lucrative public contracts in the construction sector. Engineering firms, construction companies – but also the mafia – were particularly targeted by these allegations. Wanting "to have access (to) a precise and relevant information about the situation" (author's translation)[3] (Ipsos Descarie 2011, p. 2), the OIQ appointed a polling firm to collect this information, by means of individual interviews, of focus groups and a survey among its members. Sent to 57,911 members of the OIQ, the survey showed a response rate of 16.1% (9352 respondents), with a statistical margin of error of ±1.0%, 19 times out of 20. The results to which we shall refer to in the two subsequent sections of our analysis can thus be considered as very reliable.

Our third source of information is the ethical diagnosis made in 2013 and 2014 under the responsibility of the co-researchers Bégin and Langlois in a public organization employing more than a hundred engineers (Bégin et al. 2014).[4] Essentially, this public organization was reacting to public allegations regarding practices within the organization. The mandate did not aim at all at the organization's contractual practices. The report highlighted six items in particular, one of which was the specific situation of the engineers within the organization. We shall refer to some of the relevant data in this respect from the report.

We shall thus rely on the results obtained within these three mandates. These results appear to us to overlap and complete analyses that we can find in the relevant scientific literature. It is worth mentioning, furthermore, that we approached these three mandates both from the field of expertise in applied professional ethics and from the field of organizational ethics. We see professional ethics as being essentially preoccupied with ethical questions and problems that emerge from professional activities, from contexts regulating these activities (business ethics, regulations, etc.) and from contexts in which the professional practice takes place (private practice, business practice in a company, practice within public services, etc.). As regards organizational ethics, we were concerned with the ethical issues that arise, particularly, but not exclusively, within organizations characterized by regulatory models and hierarchical labor relations, and where functions and roles are assigned to the individuals who work there. In these organizations, we can find several regulatory modes (labor contract, administrative rules, professional business

[2] L. Bégin and A. Lacroix took part in designing this survey and in the interpretation of the results on behalf of the OIQ. An important part of this private survey was made public recently because the OIQ was compelled to give it to the commissioners within the framework of the Commission of inquiry on the construction industry (the CEIC). For reasons of confidentiality, we will return only to the sections made public.

[3] The following translations from French are marked only with the abbreviation (a.t.).

[4] For reasons of confidentiality, we will not name the organization in question and we will not reveal in a very detailed way the principal results. We will limit ourselves in mentioning only certain data that do not reveal the content of the diagnosis produced for this organization.

ethics, diffuse rules of the workplace, etc.) that do not always lead to a harmonious and effective coordination of the workers' conducts (professionals or otherwise) and do not always produce results that are socially acceptable and responsible. Because our contribution specifically concerns salaried engineers working within organizations we mobilize again these two domains of applied ethics.

4.3 Multiple Loyalties

The first phenomenon that makes the actualization of the engineers' professional ideal problematic is multiple loyalties. Québec's legislation, as with others, states that loyalty is expected of every person working for a professional organization. It implies that a salaried employee must act with caution and diligence in the exercise of his duties, so as to avoid causing prejudice to his employer. In the same manner, she/he will have to show restraint in his comments concerning his employer and cannot display publicly his differences with the latter. But it will not prevent her/him from also being a professional – particularly relevant for an engineer – and to be bound by commitments and obligations specific to this status. An engineer can also feel a form of commitment towards his colleagues, whether they are members of her/his own profession or not. Expectations are related to each of the roles inhabited by this person (employee of the organization, member of a professional order, colleague, labor union member) and thus requires a form of loyalty. Loyalties are thus at the heart of numerous and tangled up commitments, obligations, and expectations (Centeno and Bégin 2015). Although loyalties are numerous for every salaried professional, they not conflicting per se. Indeed, the fact that a person has to live in a situation of multiple loyalties in the workplace does not necessarily imply that this person will go through important difficulties or conflicts because of these diverse commitments. However, the potential for conflict is very real (Emmet 1975, p. 159). A conflict of loyalties arises when the professional finds herself/himself in a situation putting stress on diverse commitments that he took, and thus forcing her/him to be unfaithful to some of them and, at the same time, to the people with whom he made these commitments. As underlined by M. Martin and R. Schinzinger (1983, p. 187), "The relationship between loyalty to employers and other professional obligations is complex. Loyalty to employers can mean (1) meeting one's moral obligations to employers – in which case loyalty is automatically good; (2) being zealously supportive of the employers' interests – in which case there are limits to how far loyalty is good." A classic form of conflict of loyalties for a salaried engineer will present itself when the latter is required by her/his employer to act in a derogatory manner concerning her/his professional obligations or, more widely, to go against the essential values of the ideal of his profession.

Although the legislation contains the obligation of loyalty to employers, the situation of the salaried professional is singular in that an essential element of the professional activity is the independence of judgment and action.[5] As Vandenbroek emphasizes in reference to the professional practice of engineers, "to safeguard his professional independence, one must preserve the capacity to act in accordance to his profession and protected from any sort of intervention, may it be real or apparent, coming from any person, employer or customer included" (a.t.) (1993, p. 94). For that reason, according to Québec's jurisprudence on the subject, loyalty to the profession and to ethical obligations has precedence on the terms of the contract binding the professional to an employer (Sullivan and Tremblay 2007, pp. 40–41). This priority of loyalty to the profession and its values is recognized and asserted by some of the engineers that we met in an interview during our research mandate with a public organization in Québec employing a few hundred engineers. For example, one of them told us: "we have to ensure our loyalty to our employer but not beyond certain […] principles of ethics and values" (a.t.). In the same manner, another asserted that: "an engineer is first and foremost an engineer, before being an employee of the State" (a.t.) (Bégin et al. 2014, p. 43).

At the same time, we shall not be surprised to find that such conflicts of loyalties can also be resolved in spite of or to the detriment of the profession' values and ideal. This emerges from the answers to some of the questions of the 2011 OIQ survey. To document the phenomenon of wrongdoings, we asked engineers participating in the survey if they, during the last 5 years, had been a direct or indirect[6] witness of certain suspicious situations concerning the granting of contracts in their sector of activity. These situations of malpractice were: favoritism, low bidding with catching up (the case of extras), conflicts of interests, fragmentation of the bidding procedures to bypass rules, bribes, false representations, collusion, breach of confidentiality, contribution to one or several political parties to maintain affairs (forbidden in Québec by the electoral Law), plagiarism of engineering documents in the submissions.[7] Another question concerned wrongdoings concerning the delivery of mandates. Sixty-one percent of the responders said that they had been direct or indirect witnesses of at least one of the wrongdoings enumerated in the first question. Once the data had been divided along these lines, we found that 52% of all the engineers admitted that they had witnessed indirectly one of these wrongdoings and 33% had been direct witnesses of at least one of them. As for wrongdoings concerning the delivery of mandates, 64% of the responders asserted that they had been direct or indirect witnesses during the last 5 years (48% witnessed at least one of the wrongdoings in an indirect

[5] Freidson affirms this need for independence in a particularly strong way: "Professional ethics must claim an independence from patron, state, and public that is analogous to what is claimed by a religious congregation". (Freidson 2001, p. 221)

[6] A "direct witness" is a person who has seen and/or heard; an "indirect witness" is a person who has heard of certain problems by a credible third person working in the same sector.

[7] The order of enumeration of these wrongdoings respects their decreasing order of occurrence. Thus, favoritism is the most frequently observed (38% of the responders), followed by low bidding with catching up (32%), conflicts of interests (31%), fragmentation of the bidding procedures to by-pass rules (24%), bribes (20%), and so on.

way; 41% witnessed at least one of the wrongdoings in a direct way).[8] These figures are much more important than the survey's sponsors expected. This means that numerous engineers have had to deal with situations of conflicts of loyalties in the 5 years preceding the poll. Indeed, an engineer who are witnessing wrongdoings and who are seeking to fulfill his professional ideal whether concerning the ethics of the profession and/or its central values cannot stand idly and say or do nothing. At the same time, her/his superiors will expect him as an employee to turn a blind eye to the situation – or even to participate in it – if they are themselves the instigators of these wrongdoings or if they contribute to it. It can also involve wrongdoings committed by colleagues without the knowledge of their employers. In this last case, loyalty to colleagues may generate expectations opposite to the loyalty to the profession and to the employer. In all these scenarios, the important question for our research subject was to find out how the engineers reacted in these situations.

The survey also reveals that 73% of the engineers who directly witnessed one of the enumerated wrongdoings did act upon it. The majority of them (56%) chose to warn a person in charge of the organization. Only 3% of these witnesses decided to notify *L'Ordre des ingénieurs du Québec*, which is nevertheless the body responsible for ensuring the integrity of the professional practice of the engineers. We cannot conclude from this result that loyalty to the organization was privileged in the majority of these cases. In effect, nothing allows us to imply in any way that in all these situations – or at least the majority of them – an engineer preoccupied with his professional ideal felt that he had a duty to inform his professional order about it. Nevertheless, the very low percentage of engineers having warned the OIQ raises certain questions as regards the dominant loyalty in the practice of these engineers. These questions are all the more relevant when we notice that the results concur with those obtained in another survey that we conducted in 2013–2014 with engineers working in a public organization, and for which we produced an ethical diagnosis. In this case, less than 2.1% of engineers informed the OIQ about wrongdoings which they witnessed in the exercise of their function. This result turns out to be the more significant as almost three times more of them (6.1%) would have witnessed a breach in the professional ethics. Yet in such situations, the Code of ethics is quite clear: engineers have the duty to notify the syndicate without delay if they believe that an engineer infringes this Regulation (article in 4.01.01. g). In these few cases, the primary loyalty went to the colleagues whom they did not want to denounce to the professional practice supervisory board. Consequently it was difficult to invoke an actualization of the professional ideal.

This report is strengthened by other data from both surveys. In the 2011 survey, 27% of engineers witnessing in a direct way at least one wrongdoing did not act upon it, while this percentage was established at 17.7% in the 2014 survey. While several of them took into consideration that they had insufficient proof (48% in a

[8] Three groups show definitely larger numbers than others in witnessing various wrongdoings in the two targeted categories (the granting and the implementation of contracts): (1) the supervisors of building sites, (2) engineers who take part in the process of granting contracts, and (3) engineers who take part in the business development of their company.

case, 40% in the other), it is interesting to note other principal explanations were invoked in order to abstain from acting. These explanations which include the sense of powerlessness, the lack of confidentiality or anonymity in a case of denunciation, the fear of reprisals, as well as the desire not to harm a colleague or a company, are equally common to both surveys (every explanation is put forward by approximately 20% of the engineers that did not act). "Not wanting to harm a colleague or a company" is particularly significant concerning the order of priority of the engineers' loyalties, in that it indicates a loyalty to other commitments than those associated with the professional ideal.

These few data show the difficulty to which an engineer becomes subject when working within an organization as a paid employee. She/He then finds herself/himself at the center of a set of commitments, expectations, and obligations that do not always favor an actualization of the values and ethics of the professional ideal. The phenomenon of the multiple loyalties is very often translated into conflicts of loyalties which force the engineer to make choices that sometimes turn out to be very difficult (Langlois 2008, pp. 43–46). Besides the fact of a loyalty sincerely assumed towards the colleagues, the company or the organization for which the engineer works, it is worth considering other factors which can explain the lack of motivation in prioritizing loyalty to the professional ideal. Both surveys also reveal the importance of the other reasons – already mentioned – not to act in situations of wrongdoings: the sense of helplessness, the lack of confidentiality or anonymity in the case of denunciation, and the fear of reprisals. Yet these reasons have the unusual feature that they show the feeling of powerlessness that engineers experience when facing these situations. And this feeling of powerlessness becomes an obstacle to the actualization of the professional ideal.

We can quickly analyze the question of this feeling of powerlessness by recalling a well-known characteristic of professional activities: the power asymmetry between the professional and the customer. In the standard situations of a professional practice, a customer finds himself in a position of relative weakness in front of the professional. Sullivan reminds us that professional services "[…] are often beyond lay ability to understand fully or to judge. There is thus an inescapable relationship of trust between practitioner and client involved in any successful professional enterprise" (1995, p. 147). Because of this power asymmetry, it is essential to protect the customers against possible abuses committed by professionals, to the detriment of their customers. The Québec professional system was set up with the objective to reduce as far as possible these risks of abuse. But in a situation of paid work, this power asymmetry is in itself fundamentally modified. When the engineer is salaried, the person who requires his services and who is his customer is also, *in reality*, his employer.[9] As a customer, the employer "concedes" a form of power to the professional but as an employer he has an undeniable stronghold over the professional. If he cannot exercise the professional's expertise – which effectively puts the

[9] The *Code of ethics of engineers* stipulates it clearly: "1.02 In this Regulation, unless the context indicates otherwise, the word "client" means a person to whom an engineer provides professional services, including an employer".

employer-customer in a position of partial vulnerability – he can nevertheless impose his guidelines and his choice of actions, thereby putting the professional in a real position of vulnerability. Because of imperatives of cost efficiency and greater profits, we can easily imagine that employers-customers might require from engineers working for them that they act in a way that is detrimental to their professional obligations and against the central values of their profession. The power asymmetry thus being inverted, the engineer can fear that a refusal on his part might entail forms of reprisals, going from a loss of any possibility of advancement within the organization to a pure and simple dismissal. Naturally, the pressures exercised can be very diffuse. But the fact remains that when mentioning "fears of reprisals", "lack of confidentiality", or "sense of powerlessness", the engineer expresses his awareness of his position of vulnerability.

These fears are certainly not excessive. The works of the Commission of inquiry on the construction industry (CEIC) documented certain situations where whistleblowers found themselves in difficult positions. A particularly interesting case is one of a junior engineer, K. Duhamel, who tried to denounce an obvious situation of wrongdoing to her superiors (CEIC 2015, p. 44). Dissatisfied with the absence of will to rectify the situation, and in spite of barely veiled threats implying not to follow up on any more of these accounts, she then resolved to inform her superiors. The result was that she found herself allocated uninteresting tasks, without any link to her real qualifications, and especially very far from the theater of operations of the wrongdoings. Disgusted, she voluntarily quit her job with her employer but had immense difficulties finding a new one. Apparently, the reputation of being a whistleblower spreads and the employers are not inclined to trust them because they are afraid – as we can believe – that these "inflexible" defenders of the professional ideal will find some of their own practices at fault.[10]

To conclude this brief analysis, it seems reasonable to assert that the phenomenon of multiple loyalties plays a crucial role in making the actualization of the engineers' professional ideal more problematic. The data in our two baseline surveys indicate that engineers experience obvious tensions between the diverse loyalties that challenge them, and that the end result is not to the advantage of the professional ideal. For some of these salaried engineers, and to their detriment, we can presume that their position of vulnerability obviously gets the upper hand over the actualization of the professional ideal. In these situations, the engineer knows what values are expected by the profession but cannot resolve to assume the risks that it involves: the conditions in which he finds himself are not favorable to an actualization of his professional ideal.[11] The second phenomenon to which we shall now pay attention is the de-professionalization process. Here we shall analyze obstacles that will likely affect the conditions of an actualization of the engineers' professional ideal even stronger.

[10] It is obviously not a typically Québécois phenomenon. See, in particular: Thompson (2005, pp. 245–266) and Schehr (2008, pp. 149–162).

[11] We can read a disconcerting testimony of this kind of situation in a text with a revealing title: "I Gave Up Ethics – To Eat!" (Consulting Engineer 1983, pp. 233–238).

4.4 The De-professionalization Process

While multiple loyalties force the salaried engineer into situations of difficult choices, the de-professionalization process shows us the engineer losing the fundamental marks of his professional activity.[12] The work of an engineer as an employee within an organization may lead to the phenomenon of de-professionalization which can take one or another of two forms that will often be complementary. In the first one, de-professionalization is to be understood as a decrease – or even a complete atrophy – in exercising an autonomous professional judgment. In the second, there will be a weakening – if not the disappearance – of the salaried engineer's professional identity. In both cases, the effects of this process will be apparent on a continuum: as it becomes more or less radical, the de-professionalization process will leave us in the presence of professionals for whom the practices are partly – if not wholly – disconnected from the constituent values of the professional ideal. The hypothesis that is put forward here is not that these engineers would act against the values of their profession. It is rather that these values and the professional ideal that they express stop being marks or guiding principles directing the engineer's practices. Thus the hypothesis of the de-professionalization process does not assert that certain groups of engineers would be deliberately deviants to their professional ideal; it rather demonstrates that their employee's activity does not relate anymore to this ideal. We cannot obviously exclude that in certain situations some of these engineers can also be deliberately deviants. Because the de-professionalization process occurs gradually, we can presume that some awareness of acting in a deviant way sometimes emerges in the first stages of the process. But once the break with the axiological and normative marks of the profession becomes clear, the awareness of acting in a deviant way inevitably loses its meaning.

The first form of de-professionalization is the easiest to document. Asserting the autonomy of professional judgment is at the heart of the classic model of professionalism and it is one of the principal conditions required in Québec's professional system in recognizing an activity as aspiring to the status of 'profession' (Professional Code 2016, article 25, paragraph 2). Nevertheless we notice that the massive increase in the number of salaried professionals, combined with market pressures and transformed operating methods of work organization, contributes to a weakening of this professional autonomy. Additionally professional expertise has increasingly become subject to the standards of efficiency and profitability (Boussard et al. 2010; Centeno and Bégin 2015). In general, the professionals – particularly those who are salaried – lose some power for the benefit of administrators, managers and leaders whose actions are guided by market logic. As the French sociologist F. Champy insists, "[…] we can ask ourselves if the members of a given profession still have the necessary autonomy to accomplish their work, in accordance with the knowledge, the know-how and the constitutive values that the profession's common

[12] We use the concept of de-professionalization in a way that differs from that of Freidson (2001, p. 129). Freidson refers to the loss of the status of the profession.

culture would allow them to do in the absence of outside interference" (a.t.) (2009, p. 203). In the absence of such autonomy, we do not see any more how the professional ideal could possibly be actualized.

These shortcomings in exercising a professional judgment for engineers were clearly documented in the case of the collapse of the Boulevard de la Concorde overpass, for which we submitted an ethical diagnosis for the benefit of *L'Ordre des ingénieurs du Québec*. Directly implicating Québec's Ministry of Transport – which had the responsibility of supervising and controlling both the construction and the maintenance of the road infrastructures – the Johnson Commission report formulates a very clear recommendation for that purpose:

> The Commission is of the opinion that the Ministère must take action to address shortcomings in respect of its work, notably, as regards to poor record keeping, unclear accountability and the apparent difficulty of engineers to impose their professional judgment. The Ministère should implement an action plan to rectify this situation. (Commission of inquiry into the collapse of a portion of the de la Concorde overpass 2007, p. 182)

This "apparent difficulty of engineers to impose their professional judgment" must not be understood as an exclusive reference to their technical expertise. A professional judgment also includes reasoning capacities directed at finding an adequate solution in a given context. It implies the capacity to determine in an autonomous way the best course of action, by taking into account at the same time a problem's technical specifications, the expectations and needs of the customer, as well as the current rules and the predictable consequences of the activity in question for the company. For that purpose, the Québec's Interprofessional Council – an advisory body set up by the professional orders – underlines that the exercise of a professional judgment requires the professional competence, understood here in a wider sense than only a technical skill:

> Indeed, beyond the knowledge and the skills proper to a domain, the professional has to demonstrate a capacity to integrate and to apply them in diverse and complex situations, at the service of a customer or an employer, and in the prevention of the damages for the latter. We are then speaking about a code of ethics and ethical dimensions in the appreciation of needs and services. The competence so defined supports the exercise of a professional judgment (a.t.). (2007, p. 12)

The professional judgment thus requires technical knowledge as well as the abilities and the capacities of an ethical nature that must be mobilized in contexts of risks of damage for the customer and the company. Martin and Schinzinger specified this, "Pursuing those [professional] responsibilities involves exercising both technical judgments and reasoned moral convictions" (1983, p. 191).

We can make the assumption that the salarization of professionals would nevertheless tend to reduce the professional judgment to a technical expertise thereby initiating the de-professionalization process. By subjecting a professional activity to market imperatives – or even to those of bureaucratization[13] – we indeed witness

[13] Fully realized, ideal-typical bureaucracy is intrinsically at odds with professionalism, since its aim is to reduce discretion as much as possible so as to maximize the predictability and reliability of its services or products. (Freidson 2001, p. 217).

what we could qualify as overestimating the technical expertise, at the expense of the values of the professional ideal. According to Scott (2008, p. 232), the regrouping of professionals in service organizations or corporations (such as engineering consulting firms) would render professional work as well as the organization of professional services more permeable to the logics of market and profit. The professional is then more and more recognized as a technical expert but less and less as a professional that must benefit from a margin of flexibility allowing him to exercise his professional judgment.

The 2011 survey undertaken for *L'Ordre des ingénieurs du Québec* supplies revealing statistics on this issue. The following question was sent to participants: "Q10. What in the following statements represents best the margin of flexibility that you benefit from in your current work environment?". The proposed choices in the answers were the following: "Little or no margin of flexibility. I am an employee who executes the tasks which are attributed to him and who follows the employer's guidelines", and: "A certain margin of flexibility. I am a professional that profits from a certain autonomy and who is able to exercise his judgment concerning the guidelines given to him, and who even refuses to submit to these guidelines in case of a disagreement". Twelve percent of the engineers asserted seeing themselves as employees forced to follow the guidelines and the demands of their employer. In other words, these engineers perceived themselves as mere agents. This result deserves to be linked to the statistics concerning engineers who in the presence of wrongdoings either took or did not take action. We can reasonably surmise that the less an engineer considers himself having a margin of flexibility, the higher the risk of turning a blind eye to certain wrongdoings that would be disapproved in the light of his professional ideal. This hypothesis would, however, need to be confirmed. It is also likely that the decrease in – and even the disappearance of – the exercise of an autonomous professional judgment will result in a weakening of the engineer's professional identity. At least, the following question is worth considering, namely: if an engineer comes to perceive himself as a mere executant, what incentive does he have to identify himself as a professional?

However the issue concerning the relation between the engineer and his professional identity remains meagerly documented.[14] That is why the discussion of the second form of de-professionalization – the weakening of the professional identity – rests more on hypotheses than on convincing data. Advancing the hypothesis of a weakening of the engineers' professional identity signifies support for the idea that, at some point, this identity stops being a dominant reference or principle of action for the respective engineer. Consistently, it is postulated that the conduct of these agents is more directed towards standards, values and expectations connected with other different positions that they occupy within the organization. This question also relates to the conflicts of loyalties: the second form of de-professionalization happens when an engineer occupies more than one role and finds herself/himself at the heart of several commitments. This is when the risk of an "identity crisis" occurs

[14] One will find nevertheless in Langlois (2008) the results of interviews of design engineers that go in the same direction of the proposals that we are outlining.

or, most likely, a change of paradigm that "translates into the progressive, but constant disappearance, of the sense of belonging to a workgroup" (a.t.) (Lacroix 2011, p. 74). In this particular case, allegiance to the profession and its ideal is gradually subdued to the advantage of an organizational identity. Gunz and Gunz (2007) present the organizational identity in the following way:

> The «organizational» identity is that of a professional who has taken on some of the characteristics of a non-professional employee of the NPO [non-professional organization], in the limit, seeing him- or herself as an employee who just happens to have, for example, a law, accounting or engineering degree. This identity is more likely to be associated with proletarianization, which proposes that professionals become like other employees of the NPO. (2007, p. 855)

For the authors, in a situation of conflict between ethical elements of their profession and ethical elements of their organization, salaried employees will almost certainly choose the action that corresponds to the identity which has come to be the dominant for them. Having said that, this dominant identity may not be an informed choice dictated by personal interest (Solbrekke 2008, p. 491): the de-professionalization hypothesis is different in this respect in claiming that a behavior dictated by fears of reprisals, become a subject of vulnerability – an issue which we raised earlier about the vulnerability of certain engineers battling against situations of loyalty conflicts. According to this hypothesis, if engineers favor the standards and the values of their work environment, it is because they became more significant and more rewarding than the standards and the values of their profession. We can estimate that those engineers motivated by fears of reprisals continue to refer consciously to the standards and the values of the profession even though their behavior may pull away in actualizing their professional ideal.

Certain factors contribute to increasing the likehood that organizational identity will prevail (Gunz and Gunz 2007, pp. 856–859):

- The professional dedicates more time to non-professional activities than to professional activities;
- The professional is involved in the process of strategic decision making in his organization;
- The professional does not believe that his work as a professional can be concretely rewarded by the organization (by means of bonuses or of promotion);
- The professional believes that his own work is exposed to important risks given in subcontracting.

These factors essentially demonstrate that a prioritized identity may vary according to the work contexts in which the professional asserts his expertise. This prioritized identity results from a form of negotiation between the professional and his work environment (Solbrekke 2008, p. 488). More diffuse factors such as peer approval and the need to be recognized are also important to consider.

A de-professionalization process in favor of the organizational identity would then make it possible to explain certain forms of de-responsibilityzation of the professionals. Identity provides the cognitive framework from which the work situations are interpreted. However, the organizational identities often contain rules less consensual and, especially, less explicit and demanding than those of the professional identity: the ethical challenges experienced in certain situations could then more easily pass unperceived (Butterfield et al. 2000, pp. 988–990). This weakness of lacking a moral reference for the organizational identities will be prevailing particularly in organizations whose informal cultures (Bazerman and Tenbrunsel 2013, pp. 117–127) as well as the rhetoric and representations they convey (Dryzek 1996, pp. 103–125) are hardly or not at all sensitive to the ethical dimension of the problems met in these situations. Such organizational contexts undoubtedly concur to the moral disengagement of the professionals (White et al. 2009, pp. 41–74) that are in a de-professionalization process. We will be able to interpret certain results of the 2011 survey in the light of this proposition. Let us remember that one of the questions of the survey related to the nature of the actions undertaken by the engineers when they witnessed in a direct way wrongdoings concerning the granting of contracts or the realization of mandates. Among the engineers who chose not to act, 11% of them gave the reason that it was not their responsibility to take action, which expresses an obvious de-responsibility-zation on their part. Another 3% rather justified the absence of action by stating that it was a common and accepted practice, a reality in the industrial realm. The engineers were consequently voicing an organizational identity that is apparently little worried by the ethical dimension of problems met in certain situations.

This form of de-professionalization also seems to have played a part in the events surrounding the drama of the collapse of the Concord overpass. At the very least, the Commission of inquiry's report underlines a certain laxity in the activities of monitoring and control of the Ministry of Transport's engineers over a 30 years period, even though the staff was conscious of the special character of the structure and the problems that it posed (Commission of inquiry into the collapse of a portion of the de la Concorde overpass 2007, p. 115).

The Report points, in particular, to the existence of the following gaps: the poor quality of the inspection files (p. 109), the absence of teamwork (p. 115), the absence of consultation between engineers at the time of delicate decisions (p. 101). Testimonies of engineers interviewed by the Commission also indicate a strong trend in explaining their behaviors by sometimes referring to their status of union member, sometimes to their role of adviser – rather than that of a professional – that they would hold in the organization.[15] In this last case, it allowed the engineers to walk away from their responsibilities because of an absence of feedback to their recommendations. One can then suppose that certain management practices and the organizational culture of the Ministry did not make it possible for these engineers to adequately preserve their professional identity, thus preventing the actualization of the engineer's professional ideal.

[15] The Commission notes that in the system in force in 2004 – and which still is – the engineer who calls upon the Direction des structures to obtain an expert opinion remains responsible for following up on the advice obtained. This suggests a relationship between the DS and the DT similar to that of an external consulting firm with its client rather than that of a specialised service providing support to another part of the same organisation, both being accountable for final decisions. This ambiguity of responsibilities has consequences. (Commission of inquiry into the collapse of a portion of the de la Concorde overpass 2007, p. 111). See also p. 101

4.5 Conclusive Remarks: Ways to a Solution?

The phenomena on which we focused our attention highlight the difficulties for engineers as salaried employees in maintaining high standards of professionalism. It is not so much their technical expertise that is questioned in these contexts than that of actualizing the values and ethical standards of their profession. However, we cannot disregard this second aspect of professionalism without transforming the engineer into a simple executant. Is it possible to counter or, at the very least, to limit the most negative impacts of these phenomena? The salarization of engineers is obviously not a momentary phenomenon or likely to diminish. The fact is that more and more salaried engineers are working in complex and large-sized organizations, be they public or private. Under such conditions, market logic will not be inclined to yield ground *vis-a-vis* professional logic. Nevertheless, it remains possible to react to the risk of a progressive erosion of the profession's ideal. The following three ways are worth consideration. Their application will vary according to the types of professional frameworks and acts existing in various countries or legislatures that are interested in reacting to these phenomena. The important thing is to see that they embody this frame of mind in concrete measures.

The first measure consists of setting up support and control methods in organizations employing engineers. This initiative was suggested in Québec by *L'Ordre des ingénieurs du Québec* (OIQ) and it was included in the recommendations of the Commission of inquiry on the construction industry (recommendation #28). The idea is, primarily, to make it possible for the OIQ to require certain accountability from employers and to ensure by various means that engineers work in an environment favorable to an honest practice of the profession. Such measures are not uncommon and other authorities could just as easily carry out control. Among the levers in considering this objective, one can consider those suggested by Dodek (2012, pp. 407–409):

1. The mechanisms of mandatory registration of firms and targeted organizations;
2. The emission of licenses conditional with the compliance with certain rules;
3. The obligation to transmit certain information;
4. The establishment of conformity systems including audits;
5. The imposition of sanctions.

Such measures should help the engineer to counter the vulnerability induced by his status as a salaried employee and to encourage him to settle conflicts with honesty by favoring the values and standards of the profession. In the same way, these measures would contribute to maintaining conditions more favorable to the exercise of an autonomous professional judgment.

A second path to be explored consists of supporting initiatives aiming at reducing the gap between how engineers see their own values, obligations and responsibilities, and how managers and employers see them. It is a question, essentially, of countering the de-professionalization process operating to the benefit of the organizational identity. To reach this goal, it would be desirable to set up discussions between representatives of both engineers and managers of various hierarchical levels. The idea would be to discuss various issues, which, in the organization, challenge the professional ideal, so that a better comprehension of the problems, as well as the roles by which these problems are tackled and solved, is developed. This kind of initiative encourages a more collaborative and reflexive management and is respectful of the roles occupied by everyone. The development of this kind of measure is not an easy task and it appears to require an uncommon managerial focus regarding ethical concerns. Nothing prevents us however from including this kind of measure in a number of conditions to be respected by the organization in order to obtain certain privileges related to good practices. But, in this instance, what is necessary is political will.

A final way to be explored could mobilize at the same time professional associations and regroupings as well as political authorities: ensure that the engineers profit from adequate mechanisms in order to act if need be as whistleblowers. In the mandates, which we carried out, significant loopholes in protecting whistleblowers are obstacles to the actualization of the professional ideal. Because of their vulnerability and the various pressures on them in times of problematic situations, the engineers can be inclined to move away from professional expectations concerning them. Such reactions are foreseeable in the absence of sufficient support. The idea is not so much to encourage engineers to be whistleblowers but to create conditions facilitating this course of action and, at the same time, creating adverse conditions for the deviating managers and administrators. The knowledge that such measures exist, indeed, lets us believe that those deviating managers and administrators would be less inclined to misuse the position of vulnerability of certain engineers.

Taken together, these approaches to a solution appear to us to offer certain safeguards – certainly quite imperfect but nevertheless necessary – against possible drifts that will affect the actualization of the engineers' professional ideal.

References

Bazerman, M. H., & Tenbrunsel, A. E. (2013). *Blind spots. Why we fail to do what's right and what to do about it*. Princeton: Princeton University Press.

Bégin, L., Rondeau, D., & Marchand, N. (2009). *L'effondrement du Viaduc de la Concorde: diagnostic éthique préliminaire*. Québec: Institut d'éthique appliquée (IDÉA), Université Laval Available at: https://www.idea.ulaval.ca/files/content/sites/idea/files/BeginLuc_2009_RapportVidaucConcorde.pdf Accessed: 01-07-2016.

Bégin, L., Langlois, L., & Côté, M. C. (2014). *Diagnostic éthique. Rapport final*. Québec: Institut d'éthique appliquée (IDÉA) Private Report. Prohibited Diffusion.

Boussard, V., Demazière, D., & Milburn, P. (2010). *L'injonction au professionnalisme, Analyses d'une dynamique plurielle*. Rennes: Presses Universitaires de Rennes.

Butterfield, K. D., Trevino, L. K., & Weaver, G. R. (2000). Moral awareness in business organizations: Influences of issue-related and social context factors. *Human Relations*, 53(7), 981–1018.

Centeno, J., & Bégin, L. (2015). *Les loyautés multiples. Mal être au travail et enjeux éthiques*. Montréal: Éditions Nota Bene.

Champy, F. (2009). *La sociologie des professions*. Paris: PUF.

Code of Ethics of Engineers. (2016). Available at: http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/I-9,%20r.%206/. Accessed: 01-07-2016.

Commission d'enquête sur l'industrie de la construction (CEIC). (2015). *Tome 3 du Rapport de la CEIC. Stratagèmes, causes, conséquences et recommandations*. Québec. Available at: https://www.ceic.gouv.qc.ca/fileadmin/Fichiers_client/fichiers/Rapport_final/Rapport_final_CEIC_Tome-3_c.pdf. Accessed: 01-07-2016.

Commission of Inquiry into the Collapse of a Portion of the de la Concorde Overpass. (2007). *Report*. Québec: Publications du Gouvernement du Québec Available at: https://www.bibliotheque.assnat.qc.ca/DepotNumerique_v2/AffichageNotice.aspx?idn=38092. Accessed: 01-07-2016.

Conseil Interprofessionnel du Québec. (2007). *Le système professionnel du Québec*. Available at: http://www.professions-quebec.org/index.php/fr/element/visualiser/id/12#18. Accessed: 02-07-2014.

Consulting Engineer. (1983). I gave up ethics – to eat! In J. H. Schaub & K. Pavlovic (Eds.), *Engineering professionalism and ethics*. Florida: Robert E. Krieger Publishing Company.

Dodek, A. (2012). Regulating law firms in Canada. *Canadian Bar Law Review, 90*(2), 407–409.

Drysek, J. S. (1996). The informal logic of institutional design. In R. E. Goodin (Ed.), *The theory of institutional design*. Cambridge: Cambridge University Press.

Emmet, D. (1975). *Rules, roles and relations*. Boston: Beacon Press.

Freidson, E. (2001). *Professionalism. The third logic*. Chicago: Chicago University Press.

Gunz, H., & Gunz, S. (2007). Hired professional to hired gun: An identity theory approach to understanding the ethical behaviour of professionals in non-professional organizations. *Human Relations, 60*(6), 851–887.

Ipsos Descarie. (2011). *Éthique et déontologie. Sondage auprès des membres de l'OIQ. Novembre 2011.*

Lacroix, A. (2011). L'identité professionnelle en mutation. In L. Langlois (Ed.), *Le professionnalisme et l'éthique au travail* (pp. 67–81). Québec: Presses de l'Université Laval.

Langlois, L. (2008). Une éthique à deux vitesses: dangers et répercussions sur l'identité professionnelle. *Pyramides. Revue du Centre d'Études et de Recherches en Administration Publique, 16*(2), 33–52.

Legault, G. A. (1999). *Professionnalisme et délibération éthique*. Sainte-Foy: Presses de l'Université du Québec.

Martin, M. W., & Schinzinger, R. (1983). *Ethics in engineering*. New York: McGraw-Hill.

Schehr, S. (2008). L'alerte comme forme de déviance: les lanceurs d'alerte entre dénonciation et trahison. *Médecine et Hygiène, 32*(2), 149–162.

Scott, R. W. (2008). Lords of the dance: Professionals as institutional agents. *Organization Studies, 29*(2), 219–238.

Solbrekke, T. D. (2008). Professional responsibility as legitimate compromises – from communities of education to communities of work. *Studies in Higher Education, 33*(4), 485–500.

Sullivan, W. M. (1995). *Work and integrity. The crisis and promise of professionalism in America*. New York: HarperCollins Publishers.

Sullivan, M., & Tremblay, L. (2007). Prééminence du Code de déontologie. Les devoirs envers la profession d'abord. *Plan. La revue de l'Ordre des ingénieurs du Québec*, 40–41.

Thompson, D. F. (2005). *Restoring responsibility*. Cambridge: Cambridge University Press.

Vanderbroek, F. (1993). *L'ingénieur et son code de déontologie*. Trois-Rivières: Éditions Juriméga.

White, J., Bandura, A., & Bero, L. A. (2009). Moral disengagement in the corporate world. *Accountability in Research, 16*, 41–74.

Luc Bégin MA in Philosophy, *Université de Sherbrooke*, and PhD in Philosophy, *Université du Québec à Montréal*. He is a Full Professor of Ethics at the Faculty of Philosophy, *Université Laval* (Québec). He was the Director of the *Institute of Applied Ethics* (IDÉA – Université Laval) from 2004 to 2016. Since 2008, he is the Director of the journal *Éthique publique – revue internationale*

d'éthique sociétale et gouvernementale (https://ethiquepublique.revues.org/). He is Editor of two books: *L'éthique au travail* (Liber, Montréal, 2009), *Cinq questions d'éthique organisationnelle* (Nota Bene, Montréal, 2014); Co-Editor of two other books: *L'éthique et les pratiques d'intervention en organisation* (PUL, Québec, 2015), *Les loyautés multiples* (Nota Bene, Montréal, 2015); and Co-Author of three books: *Le Québec face à la formation morale* (U. de Sherbrooke, 1984), *Éthique et ingénierie* (McGraw-Hill, Montréal, 1991) and *Former à l'éthique en organisation. Une approche pragmatiste* (PUQ, Montréal, 2017). Research areas: public ethics, organizational ethics, professional ethics, Ethical competence, Pragmatist philosophy.

André Lacroix MA in Philosophy, *Université de Paris*, PhD in Philosophy, *Université du Québec à* Montréal and postdoctoral fellow, Université du Québec à Montréal. He is a Full Professor of Ethics at the Department of Philosophy and applied ethics, *Université de Sherbrooke* (Québec). He was the Director of the *Chaire d'éthique appliquée* (Université de Sherbrooke) from 2004 to 2014. He is Author of *Critique de la raison* économiste (Liber, Montréal, 2009); Co-Author of three books: *Les approches québécoises de l'éthique* appliquée (Éditions GGC, Sherbrooke, 2005), *Quelle éthique pour la finance?* (Presses de l'université du Québec, Québec, 2013) and *Former à l'éthique en organisation. Une approche pragmatiste* (Presses de l'Université du Québec, Québec, 2017); Editor of few books: *Éthique appliquée, éthique engagée. Réflexions sur une notion* (Liber, Montréal, 2006), *Quand la philophie doit s'appliquer* (Hermann, Paris, 2014), *Redéployer la raison pratique. Pour une éthique pragmatique* (Liber, Montréal), and Co-Editor of *Marchés publics à vendre* (Liber, Montréal, 2015). Research areas: economics and social ethics, organizational ethics, professional ethics, Pragmatist philosophy and practical philosophy.

Lyse Langlois PhD. Educational administration and politics, Laval University and Post doct on Ethics, Boston College with J. Starratt. She is a Full Professor at Laval University's Department of Industrial Relations and associate dean of research at Social Science Faculty. She is a member of the Interuniversity Research Center on Globalization and Work, and Director of the Institute of Applied Ethics, Laval University. Her current research focuses on Ethical Leadership, organizational ethics and critical management. She has developed two ethical measuring instruments: Ethical Leadership Questionnaire (ELQ, 2014) and Ethical Sensitivity Questionnaire (ESQ, 2016) and has published several books and articles including *The Anatomy of Ethical Leadership*, AUP in 2011.

Dany Rondeau MA and PhD in Philosophy, Laval University, Quebec. Full Professor, Department of Letters and Humanities, Director of Advanced Studies Programs in Ethics and Ethos Research Group, Université du Québec à Rimouski. Director of the journal *Ethica. Revue interdisciplinaire de recherche en éthique*, member of the Commission on Ethics of Science and Technology of Quebec. Co-Editor of *L'éthique et les pratiques d'intervention en organisation* (PUL, Québec, 2015) and *La contribution des savoirs locaux à l'éthique, au politique et au droit* (PUL, Québec, 2015); Co-Author of *La construction du savoir éthique dans les pratiques professionnelles* (L'Harmattan, Paris, 2011). Research areas: organizational ethics, professional ethics, cultural dialogue, moral epistemology, restorative and transitional justice in post-conflict societies.

Chapter 5
Toward Lifelong Excellence: Navigating the Engineering-Business Space

Glen Miller

Abstract Nearly all engineers will have to navigate the engineering-business nexus, especially at critical moments in their careers. This chapter adopts an engineer's perspective and his or her resources *qua* engineer to develop an extended understanding of what it means to flourish in this space. As members of a profession, engineers are given some guidance on what is needed to succeed as an engineer. In both the United States and Europe, these expectations are most developed in student or program outcomes, ABET (a)–(k) and EUR-ACE, respectively. While both organizations encourage technical engineering expertise and lifelong learning, engineers are largely left to their own devices after graduation as the scope of professional concern shrinks to a list of prohibitive and preventive injunctions—do not practice outside one's competence, protect the health, safety, and welfare of the public, etc.—that are applicable to engineers of all stripes. Such a retreat is understandable, given the vastly different contingencies of engineering work. Yet this movement underemphasizes important aspects of an engineer's personal and professional development at the same time that engineers must navigate a staggering number of degrees of freedom that arise as engineering work intersects with business and social constraints and opportunities. A coherent approach to lifelong technical and non-technical development can be formed by integrating W. D. Ross's formulation of duty ethics with elements of virtue ethics. Ross's *prima facie* duties provide a theoretical framework for organizing the competing demands placed on an individual in the engineering-business nexus that extend beyond preventive-prohibitive concerns. Virtue ethics captures the longitudinal dimension of character and intellectual development over a lifetime through its emphasis on realization of potential, the development of habits, and the concepts of internal goods and practice. This framework can be used by individual engineers to evaluate their educational and career options and to navigate commercial, entrepreneurial, and social spaces in ways that are congruent with their personal ethics and that further develop their professions.

G. Miller (✉)
Department of Philosophy, Texas A&M University, College Station, TX, USA
e-mail: glenmiller@tamu.edu

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_5

Keywords Engineering ethics · Codes of ethics · W. D. Ross · Virtue ethics · ABET student outcomes · EUR-ACE program outcomes

5.1 Introduction

Nearly all engineers will encounter the engineering-business nexus, where a myriad of pressures, expectations, and possibilities will need to be evaluated in order to develop a reasonably sophisticated understanding of what it means to flourish in their lives. Most engineering takes place under some kind of business management, and engineers frequently interact with business professionals, many of whom are able or forced to treat engineering as a degree or more removed from their central concerns or to "black box" engineering in their work. The engineering perspective thus provides an important approach to the engineering-business nexus. In this chapter, I (i) defend an expansive understanding of what it means to be ethical and the approach taken in the subsequent sections; (ii) propose a blend of W. D. Ross's theory with Aristotelian ethics as a theoretical foundation, (iii) show that the expectations placed on engineers by ABET, EUR-ACE, and Western professional engineering organizations are consistent with and add important relevant details to the amended version of Ross's theory described in the first section, and (iv) map several trajectories of the multifaceted knowledge dimension of the engineering-business space, with an emphasis on how companies manage engineering "talent" and how different additional educational opportunities can affect the trajectories. The conclusion is a synthesis of these sections, and it ends with a short reflection on the relationship between ethics and design.

In the throes of the *Challenger* disaster, Robert Lund was famously asked to take off his engineering hat and put on his management hat (Rogers Commission 1986). By considering duties and virtues in the proposed framework, cognizant of professional obligations, an engineer can wisely determine which he or she will wear, or at least navigate those two often confusing spaces area intelligently. This approach also allows the engineer to think of ethics as life design, or, to borrow a phrase from Gerald McLean, "an art entailing the exercise of ingenuity, imagination, skill, discipline and knowledge" (McLean 1993, p. 26).

5.2 On the Nature and Scope of Engineering Ethics

The content of engineering ethics often centers on lists of obligatory and prohibited actions, those that engineers "shall" and "shall not" do, enjoined on engineers by their training, experience, and social role. Such an understanding of engineering ethics in solely a professional sense is just a sliver of the conception of ethics as it has historically developed. As Immanuel Kant points out in the introduction to *Grounding for the Metaphysics of Morals*, a proper determination of the space of ethics can be found in the Greek distinction between those beings that behave according to necessity, the proper objects of what the Greeks called physics, now the natural sciences, and those that depend on an element of freedom, or ethics (Kant 1993, Ak. 387). In addition to this understanding, ethics for engineers as professionals has a second component, for they must understand and decide how to incorporate ethical imperatives and expectations that come from their societal roles, which, in some countries, are partly defined by professional societies. Only after considering how professional ethics relates to the totality of ethical decisions that each person makes is one prepared to determine his or her personal and professional trajectories.

Professional ethics, especially when understood narrowly as adherence to conventions, codes of ethics, and accepted technical conventions, may be enough to make engineers rule-following employees, reliable agents for their employers, and law-abiding practitioners.[1] When engineers are employed in technical jobs by stable companies working in mature industries with reasonable and predictable job expectations, the task of integrating professional ethics into ethics broadly conceived may be simple and perhaps little may be gained by a thorough ethical reexamination. Yet even for such positions, as engineering roles change over time and opportunities vary from company to company—and even from business unit to business unit—engineers face a myriad of decisions. The compartmentalized nature of engineering ethics as it developed *qua* technical professionalism provides limited guidance on how various professional demands or opportunities, including managerial opportunities, should be evaluated. Moreover, the number of engineers working in such stable positions shrinks as global supply chains become increasingly complex, mergers and acquisitions occur frequently, and markets change rapidly. All of these cases call for a thoughtful reexamination of one's situation.

In addition to ethical issues that affect the engineer and the engineer's organizations, engineers should reexamine their contributions to their professional societies and to society in general. When engineers understand themselves as more than just technicians armed with knowledge of the engineering sciences or instruments that can be employed for the benefit of capital or government, the scope of engineering ethics necessarily expands. For example, in the last few decades, broader preventive obligations, such as the responsibility to protect public health, safety, welfare, and property, have gained prominence. For example, this shift of emphasis can be seen in engineering codes of ethics and engineering practice laws in the United States, where preventive obligations are now listed prior to the canon requiring that an engineer be a faithful agent for employers and clients. The extension of engineering

[1] My argument here can be understood to be somewhat sympathetic to John Ladd (1980) to the extent that codes are not sufficient and actions made under coercion or outside influence may have lesser moral value. Yet I think Ladd understates the performative value that such codes have in guiding engineers toward better decisions and actions that are outside of their immediate technical training and expertise as well as the deliberative development that has resulted in the codes of ethics for professional societies. My views are more aligned with Michael Davis (1991), who explains professional ethics as a "convention between professionals" that results in the development of a useful ideal to solve a coordination problem, which also avoids the atomistic individualist trap that seems to capture Ladd.

ethics to include societal and environmental dimensions of engineering work and one's responsibility to the profession has been dubbed "macroethics" by Joseph Herkert (2005). If such an expansion is accepted, competency in technical tasks and present job responsibilities is a necessary but insufficient condition for an engineer's behavior to be considered "ethical," even without considering how personal aims are affected by one's work.

By overlaying Herkert's distinction between microethics and macroethics with McLean's (1993) earlier delineation of engineering ethics, a comprehensive understanding of ethics for engineers can be brought into relief. McLean divides the space of engineering ethics into three areas. Technical ethics is comprised of decisions that can be made with engineering training. Professional ethics set minimal standards determined by laws, codes of ethics, and common business practices, and requires the engineer to be "part technician, part manager" (McLean 1993, p. 25). Social ethics captures the impact of engineering projects on the public well-being. Herkert's microethics roughly corresponds with McLean's technical and professional ethics, though it has fewer resources to address the challenges facing the engineer as manager. Herkert's macroethics follows the spirit of McLean's social ethics while also giving explicit attention to environmental issues. In McLean's assessment, professions had done little regarding questions of social ethics, which is "lamentable given the increasingly technological nature of our society" (McLean 1993, p. 25). As a solution, he prescribes a "design education" (McLean 1993, p. 26).

In this education, the "central focus is design, an art entailing the exercise of ingenuity, imagination, skill, discipline and knowledge based on experience" (McLean 1993, p. 26), and this perspective can serve as the inspiration for ethics understood comprehensively. The ethical task for those navigating the engineering-business space must integrate many components often considered independently. Engineers are individuals (a) whose work is often important but may not be definitive; (b) who are navigating continuously changing social, technical, environmental, and regulatory environments; (c) who have skill sets (technical, managerial, entrepreneurial) that can be developed over the course of a career; (d) who develop products or services that can improve the quality of life of many individuals; and (e) who are collaborators with other individuals, of varying moral caliber, working in organizations that are, to greater and lesser degrees, concerned with their contribution to society, to the welfare of their workers, and their effects on society. As professionals, they are expected to do their work competently and honestly, to manage their personal and professional spheres, and to direct their work with attentiveness to social and environmental concerns, all the while developing their abilities and pursuing their own goals.[2]

[2] According to Christelle Didier (2015), the European approach to ethics has much in common with the multifaceted approach described above. She describes the first European textbook as investigating three levels: "The first deals with the microsocial level and concerns ethical problems encountered by individual engineers (dilemmas and cases of conscience). The second focuses on the mesosocial level, where the technical systems and institutions are in competition. A third emphasizes the macrosocial level and therefore technical development in general as a societal question."

The multifaceted space described above may be delimited by but cannot be navigated by a set of minimal standards. Instead, a framework that is substantive enough to provide guidance yet flexible enough to adapt to different social, economic, and organizational contexts is needed. The central aim of the chapter is to offer such a coherent framework, grounded in ethical theory, informed by professional ethics, and aware of broader social opportunities and responsibilities, that can assist in the art of navigation.

The aim for coherent integration implies that an approach based on theory is more likely to succeed than one that proceeds casuistically. By definition, ethical theories at least aim for coherence and comprehensiveness to the degree possible: they try to consider the moral agent in his or her entirety. Incorporating professional concerns, then, becomes a task that resembles interpolation more than extrapolation: one must show that professional demands do not contradict the ethical theory, and, ideally, follow from or are supported by its ideas. This approach is more likely to yield a coherent whole than one that starts from specific situations or concerns.

5.3 Fusing Ross's *Prima Facie* Duties with Aristotelian Virtues

The aim of this section is to flesh out the normative content of an ethical theory that combines Ross's *prima facie* duties with Aristotelian virtue ethics. First, I explain the duties and how they assist the moral decision-maker, especially when they cannot all be satisfied. Second, I do the same with Aristotle's virtues of thought and virtues of character, often referred to as intellectual and moral virtues. For the former, the five virtues described by Aristotle in Book VI of *Nicomachean Ethics* are explored, whereas for the latter the focus is limited to its three cardinal virtues. Throughout the section, Ross's and Aristotle's ideas are applied to engineering situations.

The three main theories that receive the most attention in philosophical literature and engineering ethics are utilitarian ethics, duty ethics, usually in its Kantian formulation, and virtue ethics. These theories have been charged with providing inadequate guidance to practitioners who are faced with moral dilemmas. For example, the "greatest good for the greatest number" is difficult to determine and may result in a disproportionate distribution of pleasures and pains, the universality of Kant's categorical imperative necessarily overlooks contextual details of a particular situation, and an exhortation to prudence may not help come to a concrete decision.

I propose that the theory of W. D. Ross is more promising than these popular theories because it combines a robust concern for personal development (in self-improvement, the desire for knowledge, and the development of virtues) with concern for general welfare and the reasonable demands that arise from one's relationships. While Ross is often considered a deontologist, his theory is at least open to pluralistic interpretations, and the stress that I put on virtue makes it a blend of elements of all three theories. His theory, which posits six categories of duties that are often in conflict, gained in popularity because it reasonably described the kinds of conflicts that practitioners met on a daily basis and it provides some substantive guidance. He developed the duties primarily in his 1930 book *The Right and the Good*; his ideas can be further fleshed out by reference to his Gifford Lectures of 1935–1936, published as *Foundations of Ethics* in 1939, though his aims are broader in this work. While Ross was one of the influential moral philosophers of the early twentieth century, his theory fell from popularity before it, or at least its spirit, was revived mainly by those working on professional ethics.[3] Somewhat surprisingly, perhaps caught up in the spirit of his age, Ross's theory does not develop the sense of self-development, even as he was the foremost translator of Aristotle, the preeminent virtue ethicist, in the first half of the twentieth century.

5.3.1 Ross's *Prima Facie* Duties

Ross (2002, p. 21) posited that there are six categories of duties that are morally relevant. They are duties of

- Fidelity and reparation: one should speak the truth, keep promises, and make retribution for harms caused;
- Gratitude: benefits bestowed on an individual by another may give reason to privilege that person over another;
- Justice: one should act in such a way that the distribution of happiness to merit should be proportionate;
- Beneficence: one should improve the lot of others;
- Self-improvement: one should improve one's capabilities; and
- Non-maleficence: one should not cause harm.

Ross calls describes these responsibilities as *prima facie* duties, i.e., apparent duties, or duties at first glance, which may or may not retain such a status after further analysis. Absent other moral concerns, each duty can be a duty proper, i.e., the determinant of a morally obligatory act. Yet in many cases the actions that would satisfactorily fulfill one duty differ from and exclude the ones that would satisfy other duties. In these cases, the task of a moral agent is to evaluate the relevance and strength of the competing duties to determine which should hold sway.

It is important to note that these duties differ from the universally binding sense of duty that is associated with Kant's theory, due to the latter's prevalence in the literature. Kant calls universally binding duties "perfect duties," that is, those that hold categorically, must always be satisfied, and can never be in conflict (Kant 1993,

[3] The most prominent example is Beauchamp and Childress's *Principles of Biomedical Ethics* (sixth ed., 2009), which has become the model of other areas of professional ethics. Ross is only mentioned a couple times, but their basic or "mid-level" principles operate similarly as Ross's duties.

Ak. 421–424). Ross's duties are similar to what Kant calls "imperfect duties," which should be satisfied as best as possible but which are often in conflict. In the *Grounding for the Metaphysics of Morals*, Kant gives two examples of imperfect duties, beneficence and self-improvement. Ross's theory does not segregate classes of duties or give an *a priori* precedence to some over others.

The idea of competing duties is illustrated in the following hypothetical situation: an engineer thinks it possible that his company may be releasing a pollutant as part of a beneficial economic process that may cause minor harm to a few members of the community. When deliberating what to do, the engineer may recognize that several duties apply, and they recommend different actions. On the one hand, the engineer should be loyal, which can be construed as a combination of fidelity and gratitude, to the employer, who should expect that its employees act in, or at least not against, its interests. Moreover, the duty of beneficence encourages acts that benefit the majority. On the other hand, non-maleficence, which is owed implicitly to the entire population, and justice, if the suffering is disproportionate, suggests an obligation to address these issues, even if such actions may harm the employer's interests. The task of the moral agent is to determine the appropriate act in this situation, which requires differentiation between the different competing obligations. If the agent determines that non-maleficence and justice are most relevant, the duties of fidelity, gratitude, and beneficence were apparent duties.

In the previous example, fidelity, gratitude, and beneficence are ultimately recognized as apparent duties, but they still refer to actual moral considerations. As such, duties that are found to be apparent are not fully discharged by right action. These unsatisfied duties maintain a moral force, which Ross calls moral remainders: "when we think ourselves justified in breaking, and indeed morally obliged to break, a promise in order to relieve some one's distress, we do not for a moment cease to recognize a *prima facie* duty to keep our promise, and this leads us to feel, not indeed shame or repentance, but certainly compunction, for behaving as we do; we recognize, further, that it is our duty to make up somehow to the promisee for the breaking of the promise" (Ross 2002, p. 28). Such residual moral demands prompt further moral deliberation and often subsequent actions.

Along the same lines, when an innocent party is harmed, even if it was unpreventable, the duty of justice requires some retributive action. This requirement holds whether the party is one person or a group, and whether the moral deliberator had full control of the situation. In a reflection about justice, Ross says that "many of the existing injustices are due to a social and economic system which we have, not indeed created, but taken part in and assented to; the duty of justice is then reinforced by the duty of reparation" (Ross 2002, p. 28). In the engineering-business space, this idea has many applications. Take, for example, where a situation where senior management promotes an employee over another for reasons other than merit: in this case, an engineer working as manager may have some outstanding duty to offer some compensatory benefits to the snubbed employee in the future, by virtue of participation and assent to the systems that are used to govern the company.

Ross's duties lead to more than simply a justification for obligatory or prohibited actions, on which engineering codes of ethics and laws governing engineering practice generally focus. The duties of self-improvement and beneficence can be considered as contributions to the overall good, or, phrased in a way that keeps with the spirit of Ross, increasing the lot of intrinsic goods. The four intrinsic goods Ross identifies are virtue, knowledge, pleasure, and justice. Virtue and knowledge are most relevant to the present inquiry. Knowledge of the engineering sciences is an important characteristic of engineering professionals, and some understanding of business processes, terminology, and financial operations are necessary for managers. (The question of how to assess, organize, and obtain knowledge deserves a separate investigation.) Some principles to guide such decisions can be found in a closer investigation into virtue, which I think is an essential complement to his duties for those working in the engineering-business nexus.

Unfortunately, Ross provides little detail of what he means by virtue. When referenced in *The Right and the Good* and in *Foundations of Ethics*, he merely mentions the importance of moral and intellectual virtues, never adding an adequate explanation. This shortcoming can be traced to the singular emphasis that Ross puts on the act undertaken in a particular situation, which Thomas Hurka has called an "occurrent state" understanding of virtue ethics (Hurka 2006). Aristotelian virtue ethics differs by giving attention to the disposition that leads to an act. Dispositions, like muscles, can be developed through repeated action, and they persist in an individual, whereas acts do not accrue, even if their consequences persist through time. Squaring the meta-ethical problem between the two approaches to virtue ethics is beyond the scope of this chapter. Here, I will simply proceed by assuming that such integration is possible and adopt an Aristotelian framework to add flesh out the virtues.

5.3.2 Aristotelian Virtues of Thought and Character

Ross followed Aristotle by distinguishing intellectual virtues from moral virtues, or, as Joe Sachs, a contemporary translator of Aristotle, expressed more clearly, virtues of thought from virtues of character.[4] Virtues of thought are acquired through instruction and experience. These virtues can be divided into two groups, those that have to do with the contingencies and those that have to do with things that are not. The first virtue of thought, prudence or *phronesis*, is the virtue of judging the various aspects of a particular situation, which is always unique, in order to come up with a correct judgment. Prudence has been called the queen of the virtues because it is the virtue that makes the virtues of character possible. The second virtue *techné,* from which the English words technology and technique are derived, is the virtue of taking into account all of the relevant factors to determine how to bring about some state of affairs. *Techné* differs from prudence in that the latter results in judgment and

[4] Sachs's translation of *Nicomachean Ethics* (2002) was published in Newburyport, MA by Focus Publishing. The virtues of character are described in Books II–V and the virtues of thought in Book VI.

action, not making or bringing something into existence. While *techné* was often associated with forging artifacts, it was also used in ancient Greece to describe bringing about some state of affairs, notably justice in Plato's *Republic*.

Both virtues are important for engineers. The virtue of *techné* is developed in part on the mathematics and sciences, including physical and engineering sciences, that are learned in an accredited engineering program. The virtue of prudence is even more fundamental: it determines *when* the virtue of *techné* is applicable, which suggests that an engineer's education and experiences must be broad enough to allow them to make such judgments.

A third virtue of thought, *episteme*, permits one to reason with certainty from hypothesis to conclusion, which is often used to connote the search for universal truths associated with the practice of science, or by using syllogisms. Unlike *techné*, *episteme* does not depend on context or conditions: the truths that are derived from it are necessarily true. The recognition that what so many engineers and scientists do today is technoscience blurs the division made by Aristotle: engineers utilize and find scientific theories, scientists introduce technology into their experiments, and the modern scientific project is structured more like a technological project than an attempt to reveal the truths of nature.

A fourth intellectual virtue, *nous*, means the pre-rational grasping of the essential nature of a thing or situation. The virtue differs from intuition in that the latter usually makes leaps beyond what can be discerned, whereas *nous* grasps exactly and perfectly what is known. It allows its practitioner to know with certainty that something is the case without going through a stepwise rational explanation of it. Applied to engineering, a colleague of mine is able to tell how a nuclear power plant is running based on its sounds. If pressed, he could explain how to tell that a certain part of the process is suboptimal and the reasoning that was necessary to come up with it, but he does not need to work through these incremental steps to draw his conclusion. He sees (or, in this case, hears) and understands the whole.

Aristotle describes wisdom, the last and final of the virtues of thought, as the ordering of the other virtues, in particular *nous* and *episteme*, toward their highest and best ends. The virtue forces engineers to move past technical expertise or perfection to ask teleological questions, such as: What is the benefit of my efforts on society? Do my efforts make it more or less likely for others to live a quality life? Is there something else that I should be doing that is more noble? What are the highest and best ends, for me and for my profession? Its practice also forces the engineer to consider how well his work fits into other valuable aspects of his life. *Sophia* is especially important for engineers who are seeking to determine which knowledge they should obtain and use.

The virtues of character, for Aristotle, are learned by repeated practice that is consciously undertaken, and it results in an altered disposition that enables one to act in line with the virtue when the situation calls for it. While Aristotle lists many virtues of character, it is sufficient to focus on the three cardinal virtues of character: moderation, courage, and justice. The cardinal virtues refer to the central virtues from which all other virtues can be derived. The cardinal virtue of prudence, discussed above, is the intellectual virtue most closely related to the virtues of character.

Most virtues of character are means that fall between deficiency and excess. The mean indicates relative position, not an arithmetic point, and the mean for one individual may differ from another. For example, courage is a mean between its deficiency, cowardice, and its excess, rashness. An action that is considered courageous for one individual may be rash for another, a characteristic that is clear if one considers two individuals with different training and experience facing the same situation in a military battle: for one, the best action may to flee, and for the other it may be to hold the position. One becomes courageous through acting courageously, and these actions lead to the formation of a stable character trait or disposition that persists between such actions.

The cardinal virtue of moderation refers to the exercise of judgment over passions and inclinations so that they are satisfied only to a limited extent, or possibly not at all. Courage is the virtue that works against passions and inclinations absolutely. In the example of courage listed above, if one's inclination is fear and the action that it suggests is retreat, whereas prudence indicates that one can successfully hold the position, then the fearful inclination must be dismissed. Whereas prudence, moderation, and courage are actions and dispositions of an individual, justice is expressed across society. Justice is to give each person his or her due, a bit of a vague phrase, and a term that is even more problematic in Ross, who sees it as a state of affairs rather than a virtue. I propose that justice is both a disposition and an act, and modern understandings of justice as procedural, distributive, and environmental all are consistent with an Aristotelian understanding of the term.[5]

The virtues of character, which lead to flourishing of the person, also easily translate into the engineering and business space. Courage is more likely to take the form of speaking out against a false consensus or against a domineering manager, where the fear is ostracization or career penalties rather than physical harm or death. While discussions of moderation have traditionally focused on desires such as food, alcohol, and sex—no doubt still moral issues today, though not as important in the space of professional ethics—these discussions can easily be extended to moderating the desire for luxurious consumption, to the point where it distorts one's development, or for recognition, which should be accepted when deserved or passed on to those more deserving when it is not. And justice in the engineering-business space has more to do with treating employers, vendors, and employees fairly, avoiding conflicts of interest, following established protocols and regulations, and advocating for their changes if they are not substantively fair.

The *prima facie* duties of Ross fused with the Aristotelian understanding of the virtues provides a foundational framework for navigating ethical concerns understood broadly, and, as I have shown, for some aspects of the business-engineering nexus. At this point, it is necessary to show that this framework is consistent with

[5] Ross recognizes that justice is used to describe many things, but he limits his understanding of the term to describe "bringing about of a distribution of happiness between other people in proportion to merit" (Ross 2002, pp. 26–27).

the student and program educational outcomes that have been developed in the United States and Europe through ABET and EUR-ACE, respectively.

5.4 Compatibility of the Proposed Theory with ABET and EUR-ACE Outcomes

As Aristotle argued, intellectual discernment moves between first principles, hidden farthest from observation, and what can be immediately perceived and judged. The adequacy of first principles can be tested against what is important in specific cases in an iterative process. In this section, the compatibility of the proposed theory that blends Ross's *prima facie* duties with Aristotelian virtue is compared to the general guidance given by two influential accreditation agencies, ABET and EUR-ACE, for institutions of higher education that prepare engineers and engineering technologists. ABET requires accredited institutions to ensure that a defined set of student outcomes are met, whereas the European Network for Accreditation of Engineering Education (ENAEE) has established a set of program outcomes called EUR-ACE. In this section, I compare them against each other and against the theoretical framework proposed in the preceding section.

ABET, known as the Accreditation Board for Engineering and Technology until 2005 when it began to operate simply by its acronym, is headquartered in Baltimore, Maryland. It accredits about 3600 programs at 700 colleges and universities in 29 countries around the globe, with the vast majority located in the United States.[6] Based on guidance from engineering societies and industry, they evaluate and encourage institutions to ensure that their graduates have the "technical and professional skills employers demand".[7] It is also a signatory on several mutual recognition agreements with accreditation agencies from other countries, including the Washington Accord, which guarantees the substantial equivalency of the programs accredited by national accreditation agencies.

Students from accredited institutions are expected to have demonstrated the following outcomes, called the (a)–(k) outcomes, when they graduate with their engineering degrees:

(a) An ability to apply knowledge of mathematics, science, and engineering;
(b) An ability to design and conduct experiments, as well as to analyze and interpret data;
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
(d) An ability to function on multidisciplinary teams;
(e) An ability to identify, formulate, and solve engineering problems;

[6] ABET. "History." Available at http://www.abet.org/about-abet/history/. Accessed 06-21-2016.
[7] Ibid.

(f) An understanding of professional and ethical responsibility;
(g) An ability to communicate effectively;
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
(i) A recognition of the need for, and an ability to engage in life-long learning;
(j) A knowledge of contemporary issues; and
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.[8]

Outcomes (a), (b), (e), and (k) are closely connected with the virtues of thought of *episteme* and *techné* listed in the previous section. Outcome (c) also is, though the breadth of understanding necessary for it connects it with outcomes (h) and (j), which focus on knowledge, one of Ross's intrinsic goods, as well as the ability to either reason to (*episteme*) or grasp (*nous*) an evaluation of the entire system, which at least hints at the importance of wisdom (*sophia*). Outcomes (d) and (g) do not have a direct analogue in *Nicomachean Ethics*, though in fairness it must be pointed out that Aristotle's politics, which has to do with living in a city-state, is considered the second part of his ethics. All of these outcomes provide additional details on the kinds of virtues of thought that should be developed by engineers, i.e., they flesh out the understanding of what the virtues are.

The reverse relationship happens with two of the outcomes, (f) and (i). For these outcomes, the theoretical framework developed in the preceding sections adds valuable clarity to ambiguous phrases that can be interpreted a number of different ways. Outcome (i) can be further understood in light of Ross's duty of self-improvement, from which one should try to improve one's knowledge and virtue, as well as affect justice. Understood as actualizing potential, self-improvement is the central idea in Aristotelian virtue. An engineer in the business world is guided toward the development of both the virtues of thought, especially those mentioned above that are specific to engineering and business, and the virtues of character, which include courage, moderation, and justice, learned or ingrained through repeated intentional actions.

Outcome (f), which demands an understanding of personal and professional responsibility, can reasonably be interpreted as providing a space for the appropriate response to the *prima facie* duties listed by Ross. The content of the duties relates closely with the United States National Society of Professional Engineers Code of Ethics, which lists six fundamental canons that "engineers, in the fulfillment of their professional duties, shall" fulfill. They are to

1. Hold paramount the safety, health, and welfare of the public;
2. Perform services only in areas of their competence;
3. Issue public statements only in an objective and truthful manner;
4. Act for each employer or client as faithful agents or trustees;

[8] ABET. "Criteria For Accrediting Engineering Programs, 2016–2017." Available at http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/#outcomes. Accessed: 07-22-2016.

5. Avoid deceptive acts; and
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.[9]

Perhaps surprisingly, Ross's duty of fidelity is mentioned more than any of the others. It is central in (3) and (5), and secondary in (2), (4), and (6). The use of the term welfare in the first canon is always understood to include non-maleficence and, by some who interpret welfare broadly, to demand beneficence. Non-maleficence is also the foremost rationale for the second canon, which deals with competence. Gratitude can be combined with fidelity in the fourth canon to explain the requirement for engineers to work as faithful agents, and it can be linked with non-maleficence and fidelity to explain the obligation engineers of today have to their profession, which has been developed for several generations.

The ENAEE accreditation system is more complicated. It is an umbrella organization based in Brussels, Belgium, which was founded by six organizations in 2000 to set the standards by which first and second cycle degrees should be granted the EUR-ACE label. The EUR-ACE label ensures mutual recognition for degree programs located in different accreditation areas with the stated goal of improved academic and professional mobility for engineering students and engineers and the development of new programs. The EUR-ACE system is described as follows on the ENAEE web site:

> The EUR-ACE® system incorporates the views and perspectives of the main stakeholders (students, higher education institutions, employers, professional organisations and accreditation agencies). Professions such as engineering, medicine, architecture and others carry out work which directly affects the lives of the public. In order to assure the public that these actions and decisions are carried out safely and ethically, graduates must possess specific competences. To ensure that engineering education programmes produce graduates who can demonstrate satisfactory achievement of these competences, they are subject to accreditation by their professional body or another accreditation agency which carries out programme-based accreditation.[10]

The "Standards and Guidelines for Accreditation of Engineering Programmes" lists eight outcomes that students should demonstrate in the course of earning their bachelor's degree.[11] The competencies are summarized as follows, under the headers in italics from the ENAEE document and Roman numerals added for ease of reference.

---

[9] National Society of Professional Engineers "NSPE Code of Ethics for Engineers." Available at https://www.nspe.org/resources/ethics/code-ethics. Accessed: 06-21-2016. The canons are numbered here for ease of reference, though they are not numbered in the code of ethics. The first five canons are expounded in Rules of Practice (1)–(5), however, and the sixth canon is explained in the section titled Professional Obligations.

[10] European Network for Accreditation of Engineering Education, "EUR-ACE System". Available at http://www.enaee.eu/eur-ace-system/. Accessed: 06-21-2016.

[11] European Network for Accreditation of Engineering Education, "Standards and Guidelines for Accreditation of Engineering Programmes". Available at http://www.enaee.eu/eur-ace-system/eur-ace-framework-standards/standards-and-guidelines-for-accreditation-of-engineering-programmes/. Accessed: 06-21-2016.

I. *Knowledge and understanding* of mathematics and basic and engineering sciences, including the multidisciplinary context of engineering, as needed to achieve other program outcomes;
II. *Engineering analysis*: analyze complex products, processes, and systems; determine appropriate approaches to solving engineering problems in their field of study; correctly interpret analyses; and recognize non-technical (societal, health and safety, environmental, economic, and industrial) constraints;
III. *Engineering design*: use of appropriate methodologies to design complex products, processes, and systems that meet established requirements, while aware of non-technical considerations;
IV. *Investigations*: appropriate use of scientific literature, databases, computer simulations, codes of practice, safety regulations, and experimental research;
V. *Engineering practice*: knowledge of methods to analyze and practical skills to solve complex problems in their field of study; understanding of materials, technologies, processes, and standard practices, as well as their limitations; awareness of the non-technical implications of engineering practice; and awareness of economic, organizational, and managerial issues, including project, risk, and change management;
VI. *Making judgments* in which relevant data is gathered as necessary and interpreted correctly that take into account social and ethical issues, and the ability to manage complex projects while making responsible decisions;
VII. *Communication and team-working*, the ability to communicate information and ideas to other engineers and to the non-technical public, and the ability to work individually and on teams in national and international contexts with engineers and non-engineers;
VIII. *Lifelong learning*, which is explained as the "ability to recognise the need for and to engage in independent life-long learning" and the "ability to follow developments in science and technology."

Table 5.1 maps the 8 ENAEE program outcomes to the 11 ABET outcomes.

The high degree of correspondence between the two accreditation standards makes an extended comparison of EUR-ACE expectations to Ross's duties and Aristotelian virtues unnecessary. The focus instead should be placed on three differences.

1. The only ABET outcome that had no parallel in the EUR-ACE outcomes is (h), "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context", though EUR-ACE mentions non-technical implications, by which they mean "societal, health and safety, environmental, economic, and industrial" concerns. On this point, the ABET formulation more clearly indicates that the engineering approach may not be suitable for solving all problems, or, to put it another way, that the engineering problem solving approach is an important tool to solve some problems, but others are best addressed using other means. The EUR-ACE formulation, which follows the engineering problem solving approach, more clearly indicates stages in the process where it is especially important to include consider non-technical aspects.

Table 5.1 Comparison of ABET student outcomes and EUR-ACE program outcomes

ABET outcome	EUR-ACE outcome	Comments
(a)	I	EUR-ACE mentions the multidisciplinary character of engineering
(b)	IV	EUR-ACE has more detail, including mention of literature, databases, and simulations
(c)	III	ABET treats non-technical aspects as constraints, whereas EUR-ACE treats them as aspects, that deserve awareness; the latter could be understood as having less of a determining factor on what should be considered acceptable actions, but it also suggests that these aspects deserve concern when they do not act as constraints
(d)	VII	EUR-ACE also mentions international contexts and non-engineers
(e)	II and V	None
(f)	VI	EUR-ACE mentions non-technical implications in many of their individual items
(g)	VII	None
(h)	none	EUR-ACE mentions non-technical implications in many of their individual items
(i)	VIII	None
(j)	VIII	EUR-ACE outcomes I and III both mention knowledge at the forefront of one's specialization
(k)	V	None

2. ABET's call for professional and ethical responsibility is clearer than the minimum expected of bachelor's degree holders from EUR-ACE institutions. Instead of gaining an understanding of ethical and professional responsibility, a standalone requirement, in the EUR-ACE institutions ethical and social considerations must simply be taken into account in the course of "making judgments," which also includes gathering data and managing complex projects. Let me suggest two reasons for this. EUR-ACE is a mutual recognition agreement that includes institutions from many different countries, which makes agreement on ethical standards tougher, and European engineers are not organized in professions the same way that United States engineers are. Such limitations mean that it is not possible to harness an analogue to the NSPE Code as an extension to the EUR-ACE program outcomes. Instead, substantive content on ethics and professional responsibility must be derived through other means, which are likely culturally dependent.

   According to Didier (2015), the development of engineering ethics in Europe had less to do with professional deliberations and codes than the US model. The European approach was developed from "professional conscience intuitively sensitive to social responsibilities and to legal expectations for professional conduct" in non-German European countries. Her sociological research on French engineers, which shows that their interest and response to engineering ethics issues depends on religious practice and political orientation, raises questions about whether any principles such as those expressed in the US NSPE Code of Ethics can be assumed without careful analysis of each culture, or, perhaps more precisely, its constituent subcultures (Didier 2009). It is also likely relevant that US culture, which is more legalistic than many others, encourages ethics to be conceived as something to be followed after it is understood, like law, rather than as an essential human activity that deserves attention while leaving open the possibility that contemplation may not result in a clear and understandable course of action.

3. The detail found in the EUR-ACE outcomes, its coherence with the engineering design process, and its mention of risk, change, and project management add important details to the capabilities needed by those working at the nexus of engineering and business. Such concerns go unmentioned in the ABET student outcomes, even though the majority of their graduates will work in industry. These concerns are discussed in more detail in the next section.

In this section, I have shown consistency between ABET student outcomes and EUR-ACE program outcomes. Taken together and bolstered with detail from the US. NSPE Code of Ethics, these standards provide more than just minimal standards. They add professional engineering-specific content to the general ethical framework sketched in the second section. In the next section, I map the decisions confronting engineers navigating the expansive knowledge space of their fields, where they must be "part engineer, part manager," and, to determine this split, part philosopher.

5.5 Mapping Trajectories Through the Engineering-Business Space

The typical way that individuals with an engineering degree move into the business space is by promotion to management. William J. Lannes has described the traditional trajectory as consisting of three general phases (Lannes 2001, pp. 108–109). In the first phase, one learns and masters technical skills that are applied to a narrow field of problems. In the second, one manages projects or groups of people, often with different expertise, who are working at the first phase. The skills and knowledge that engineers broaden include organizational issues, project management, and communication. The third phase is primarily concerned with determining strategy. The individuals charged with such tasks are often executives, and the decisions they make can require knowledge about competitive positions, finance, and global trends.

Many companies now offer a dual track option, an alternative to the typical path from technical expert to management. Reports of dual tracks, separating management and technical tracks, have been traced back at least to the 1950s (Roberts and Biddle 1994, p. 562). This option is beneficial for many engineers and their companies. It provides a career trajectory that keeps engineers from "derailing" from a single track by being placed in a position in which they fail to flourish, which has been estimated to affect 10–30% of engineers in a study of Taiwanese engineers, who underperform at low levels in the second of Lannes's phases (Yeh 2008, p. 88). It provides a structure for promotions, raises, and career management for technical stars. It also helps the company to retain technical expertise and avoid the costs associated with hiring and training new technical knowledge workers. Karen Roberts and Jeff Biddle offer an added distinction to the dual track model, which is particularly helpful in mapping career goals to self-development efforts. They split the management track, differentiating between supervisory positions, which are primarily management of people, and technical and project managers (Roberts and Biddle 1994, p. 568).

Engineers who implicitly delegate the navigation of the engineering-management space to their employer are taking a significant risk because company interests rarely align perfectly with those of the employee, even though companies have an interest in retaining skilled workers. As Yeonsoo Kim, Rachele Williams, William J. Rothwell, and Paul Penaloza argue, while many companies seek to "create an environment where employees can work in multiple roles throughout their careers so that they might never need or want to take their technical skills elsewhere" (Kim et al. 2014, p. 107), "the goal of talent management is not developing employees, creating succession plans, or achieving specific benchmarks; rather, the goal is to help an organization achieve its overall strategic objectives" (Ibid., p. 94).

It falls to each employee to chart his or her own self-development. Many continuing education opportunities exist, some formal and others informal, some offered by one's company (internal) and others offered by third parties (external). I focus my analysis on one slice of the formal external continuing education opportunities, advanced degrees from colleges and universities, because these are widely available, but it may be possible to achieve the same or similar skills and knowledge using internal or informal methods. Given the multitude of specific factors that should be considered, finding knowledgeable mentors is often invaluable.

For those individuals that wish to stay in a technical track, the best higher education development efforts are a master's or doctoral degree in an engineering science, either one that deepens an existing degree. The degree could also be earned in a complementary field, perhaps one that bridges related areas of a company or manufacturing process. Frank Stefan Becker asserts that "even classical engineering tasks are shifting more and more from the construction of technical products using single components to the integration of complex sub-systems" (Becker 2006, p. 267), which suggests that an engineer who wishes to primarily do technical work should be attuned to developing the skills and knowledge needed for synthesis. Engineers may also want to consider a technical degree or certificate that would improve their portability in their company and in their industry.

Those who wish to pursue technical and project management positions have several choices, which include degrees in engineering management, project management, and other programs that develop competencies needed for success in other areas such as economics and communication. Engineering management has been described as a synthesis of disciplines, from technical to human to managerial that allows engineers to remain primarily in their technical domain (Srour et al. 2013,

p. 87). A variety of titles are used for similar programs, such as “industrial management” and “systems engineering,” and such programs are considered “process-driven” (Badawy 1998, pp. 102, 112). Project management degrees focus on the general knowledge and skills needed to successfully implement projects, with far less attention to technical details. Training in a relevant standards area, such as ISO 9001: Quality Management, may also yield some similar benefits. Advanced degrees in such areas as economics and communication usually confer benefits that are more weakly related to specific job tasks but which provide a more general and theoretical understanding of the areas that are discussed.

Those who wish to pursue management in the United States often seek an MBA, which, as Becker rightly characterizes, is “typical, well-established and costly training”—they are regarded as profit centers for universities—whereas in Europe a doctorate is the common qualification for individuals (p. 269). Another option, available at select universities in the United States and Europe, is a degree in the management of technology, which is defined by Michael K. Badawy as “the practice of integrating technology strategy with business strategy in the company. This integration requires the deliberate coordination of the research, production, and service functions with the marketing, finance, and human resource functions of the firm” (Badawy 1998, p. 95). Management of Technology is more strategic than engineering management, and it assigns greater importance to the technical aspect of organizational success than an MBA does. Those who pursue these aims usually forego technical specialization and enter a space where their technical achievements have little benefit.

The likely discrepancy in aims between engineers and their organizations means that engineers should take ownership of their navigation of the engineering-business space. As Boeing Senior Technical Fellow Mark Wilhelm said, “About 10 years out of engineering school, people have to make a choice. I’ll tell them, in the next few years you must decide which way you will go, and only you are responsible for getting the information you need to make that decision” (Owen 1999). With the stability that Wilhelm assumed no longer present for most positions, engineers are continually making choices that determine their future opportunities, whether they are cognizant of it or not, and a conscientious strategy to review one’s position at planned intervals may be helpful for many.

Such assessments share similarities with the evaluations that companies do. In order to thoughtfully navigate the space, engineers should keep abreast of industry, corporate, and business-level trends; they should identify critical job roles and skills, with an eye on present supply, the expected pipeline, and likely attrition; and they should identify the skills are of increasing value or that increase one’s options in other companies or industries. Professional societies, in their formal and informal capacities, can be of help, as can industry and government publications in these assessments. This knowledge can be used to plan continuing education credits, necessary if one is a professional engineer in the United States, or to determine which internal training one should take. While such thinking may be more “strategic” than technical experts or project managers, for example, are accustomed to doing, they are necessary to allow an engineer to set his or her path.

5.6 Conclusion

The previous four sections sketched out three different components that, taken together, can provide a robust and meaningful ethical framework that engineers can use to navigate the engineering-business space. Ross's duties, combined with the virtues of thought and character, provide a robust ethical grounding to consider societal expectations and demands and personal development. For engineers who manage people or are tasked with synthesizing efforts in fields in which they are not technical experts, these duties and virtues provide guidance for self-evaluation. ABET student outcomes and EUR-ACE program outcomes, bolstered with content from professional codes of ethics, add specific content for engineers, especially those in the first phase of their careers and those who are working on narrow technical tasks. This content includes activities that engineers should master as well as a list of prohibited actions. The range of options that can be explored in the engineering-business space, from technical expert to technical project manager to chief executive, depends on engineers learning new skills, be they managerial, interpersonal, interdisciplinary, or strategic, through formal or informal means.

To claim an appropriate measure of autonomy in navigating the engineering-business space, engineers must avoid myopia and consider how their technical efforts specifically and, more generally, how their employers, the beneficiaries of their efforts, affect society and treat their colleagues, and whether their talents should be deployed in another space. To do so allows them to make a credible claim that they are autonomous individuals, more than simply tools deployed for corporate, governmental, or other institutional powers. Moreover, an engineer must synthesize feedback from supervisors, subordinates, and clients with information about their business unit, employers, and industry, and assess how well they are meeting their other aims in life, such as personal and professional goals and familial responsibilities, in order to determine whether the path that one is on is the desired one. No small amount of self-knowledge is required in this process. Paths can be changed and different targets pursued, but major changes often curtail what one can accomplish in a career.

Because engineers enjoy a myriad of career options, categorical imperatives are certainly insufficient for navigating these decisions. Such rules provide the boundaries for what should be done, but, to adopt the language of design, they are underdetermined. To make decisions about their trajectories, engineers must practice "an art entailing the exercise of ingenuity, imagination, skill, discipline and knowledge based on experience."

A secondary consequence of the proposed normative structure of this chapter is that it refocuses ethics toward decision-making rather than judgment and toward the individual instead of the profession or to society as a whole, although the latter remains important. Engineering ethics is often explained as a set of universal standards that one either follows or does not, which allows an external observer to pass judgment on an engineer's actions. Such efforts, when successful, can only result in a set of thin ethics, which gives minimal guidance in most situations that engineers, operating as technical experts or managers, face. *Contra* Kant's categorical ideal, engineers and managers are participants, not rarified observers, in actual ethical situations in which contingencies matter and cannot be resolved by some universal law. Rather than seeing this as a frustration or constraint, such recognition permits for the development of ethics in the first person singular, i.e., what should *I* do? and should *I* support *this* project or organization? rather than focusing on the first person plural, the political sense of what should *we* be doing? or the second or third person such as an external consultant or pundit, i.e., what should *you* or *they* be doing? Such an understanding of ethics recognizes the engineer/manager as someone who can set one's trajectory, determine and gain capabilities, and shape one's profession, while always subject to a variety of outside forces. To extend McLean's analogy, the engineer is an artist not an art critic: ethics is design, and the product is who one becomes.

References

Badawy, M. K. (1998). Technology management edupcation: Alternative models. *California Management Review, 40*(4), 94–116.

Beauchamp, T. L., & Childress, J. F. (2009). *Principles of biomedical ethics* (6th ed.). New York: Oxford University Press.

Becker, F. S. (2006). Globalization, curricula reform, and the consequences for engineers working in an international company. *European Journal of Engineering Education, 31*(3), 261–272.

Davis, M. (1991). Thinking like an engineer: The place of a code of ethics in the practice of a profession. *Philosophy and Public Affairs, 20*(2), 150–167.

Didier, C. (2009). Religious and political values and the engineering ethos. In S. H. Christensen, B. Delahousse, & M. Meganck (Eds.), *Engineering in context* (pp. 417–434). Aarhus: Academica.

Didier, C. (2015). Engineering ethics: European perspectives. In J. Britt Holbrook (Ed.), *Ethics, science, technology, and engineering: A global resource*, (2nd ed., vol. 2, pp. 87–90). Macmillan Reference USA, 2015. Gale Virtual Reference Library. go.galegroup.com/ps/i.do?p=GVRL&sw=w&u=txshracd2898&v=2.1&id=GALE%7CCX3727600256&it=r&asid=8167e101948c333e22a3791e67768be7. Accessed 15 Jan 2017.

Herkert, J. R. (2005). Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering. *Science and Engineering Ethics, 11*(3), 373–385.

Hurka, T. (2006). Virtuous act, virtuous dispositions. *Analysis, 66*(1), 69–76.

Kant, I. (1795/1993). *Grounding for the metaphysics of morals* (J. W. Ellington, Trans., 3rd ed.). Indianapolis: Hackett.

Kim, Y., Williams, R., Rothwell, W. J., & Penaloza, P. (2014). A strategic model for technical talent management: A model based on a qualitative case study. *Performance Improvement Quarterly, 26*(4), 93–121. https://doi.org/10.1002/piq.21159.

Ladd, J. (1980). The quest for a code of professional ethics: An intellectual and moral confusion. Reprinted from C. Rosemary, M. S. Frankel, & S. B. Chafer, (Eds.), *AAAS professional ethics project: Professional ethics activities in the scientific and engineering societies* (pp. 154–159). Washington, DC: AAAS. 1980, With permission from the American Association for the Advancement of Science. https://www.homeworkmarket.com/sites/default/files/qx/15/03/28/08/ladd_0.doc. Accessed 15 Jan 2017.

Lannes, W. J. (2001). What is engineering management? *IEEE Transactions on Engineering Management, 48*(1), 107–110.
McLean, G. (1993). Integrating ethics and design. *IEEE Technology and Society Magazine, 12*(3), 19–30. https://doi.org/10.1109/MTAS.1993.232282.
Owen, J. V. (1999). Which path to follow? *Manufacturing Engineering, 123*(5), 80–84.
Roberts, K., & Biddle, J. (1994). The transition into management by scientists and engineers: A misallocation or efficient use of resources. *Human Resource Management, 33*(4), 561–579.
Rogers Commission Report. (1986). Available at: http://history.nasa.gov/rogersrep/v1ch5.htm. Accessed: 07-06-2016.
Ross, W. D. (1939). *The foundations of ethics*. London: Clarendon Press.
Ross, W. D. (1930/2002). *The right and the good* (P. Stratton-Lake, Ed.). Oxford: Oxford University Press.
Srour, I., Abdul-Malak, M., Itani, M., Bakshan, A., & Sidani, Y. (2013). Career planning and progression for engineering management graduates: An exploratory study. *Engineering Management Journal, 25*(3), 85–100. https://doi.org/10.1080/10429247.2013.11431985.
Yeh, Q.-J. (2008). Exploring career stages of midcareer and older engineers—when managerial transition matters. *IEEE Transactions on Engineering Management, 55*(1), 82–93.

Glen Miller BS in Chemical Engineering from Missouri University of Science and Technology. MA and PhD in Philosophy from the University of North Texas. Instructional Assistant Professor in the Department of Philosophy at Texas A&M University. Miller's research triangulates the riches of the history of philosophy, especially ethics and political philosophy, and two emerging areas of ethical concern, the environment and technology. He also teaches a large course on engineering ethics and investigates issues in applied, practical, and professional ethics.

Chapter 6
Engineering and Business Ethics: Revisiting the Higher Aims of Professionalism

Christelle Didier

Abstract The distinction between professions and occupations has been a highly controversial statement in the academic literature since its emergence. Many scholars have taken it as a fact strengthened (reflected) by the common usage. Others, aware of the difficulties of this distinction have been defining and redefining its borders theoretically. Others, who have found this distinction irrelevant or biased, have considered it as the hallmark of US cultural imperialism or as a means to hide the protectionist attitude of some privileged occupational groups behind a virtuous project (the « higher aims » of « professionalism »). Many contemporary discussions in the U.S. about engineering and business ethics take the concept of profession as central to the debate. Michael Davis aims to found engineering ethics « everywhere », by enlarging the concept of profession to engineers « everywhere », i.e. beyond the cultural and linguistic specific US context. Rakesh Khurana in turn whose goal is to re-moralize business, wants to make business a true profession, as the founders of the first U.S. MBA aimed at. Between the obviousness surrounding the concept and idea of profession and the rejection of any kind of relevance, the author of this chapter looks for a third way. She invites to replace the (Anglo-American) distinction between profession and occupation in a larger context, through a socio-historical investigation into the construction of several professional models which have structured western Europe since the Middle Age, thereby contributing to open new paths to the cross-cultural scholarly discussions about engineering and business ethics.

Keywords Engineering ethics · Business ethics · Religion · Culture · Profession · Professionalism

C. Didier (✉)
Département des sciences de l'éducation UFR DECCID, Université de Lille,
Villeneuve-d'Ascq, France
e-mail: christelle.didier@univ-lille.fr

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_6

6.1 Introduction

In 2008, Michael Davis, Professor at Illinois University and a respected scholar in the study of engineering ethics, claimed that engineers should be considered as professionals, i.e. members of a profession, all over the world, and not only in the US (Davis 2008). But he noted that the generalization to "everywhere" has been facing difficulties because the definition of engineering as a profession was not yet accepted in some countries. The reason he gave was that ordinary people as well as engineers themselves were lacking a proper definition of what it means to be a professional, and this applied even to scholars, especially in social sciences. According to him, sociologists have been unable to say if engineering was or was not a profession everywhere because of their failing to yield a satisfactory conceptual definition of profession.

With the help of a "Socratic" approach to philosophy, Davis coined a definition of profession as "a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a moral ideal in a morally-permissible way beyond what law, market, morality and public opinion would otherwise require" (Davis 1997). According to him, with this definition in hand, social scientists should be able to answer "yes" to the question "Is engineering a profession everywhere?" (Davis 2008). The consequences of this acceptation would be major on ethics education, because recognizing engineering as a profession, such as he defined it, would enable to go beyond the mere teaching of a code of ethics. It would also give a reason for engineers to obey the standards gathered in the codes.

In 2007, the American sociologist Rakesh Khurana, currently the dean of the prestigious Harvard College, published a book that was welcomed with enthusiasm and received several prizes in the US (Khurana 2007). The outcome of his ambitious socio-historical investigation was that business schools in the U.S.A. had failed to fulfill their original mission which was to pass on to managers the desire to pursue "higher aims" and make management a true profession. Instead, according to Khurana, business schools had over time lost sight of their goal. And managers had lost their legitimacy in the face of a widespread institutional breakdown of trust and self-policing in business (Khurana and Nitin 2008). Business schools transformed themselves into mere training organizations dedicated to delivering diplomas and purveying networks to students, eager to "sell themselves to the highest bidder. Khurana's book was not only a historical investigation into the emergence of business education in the US, it was also a call for a reform to re-moralize business through its professionalization.

For Davis as well as for Khurana, being a member of a profession, carrying on an activity which is considered a profession or professionalizing one's occupation, is a key issue to think ethics education for engineers and managers and to (re-)moralize business. Since the early professionalization movements of the nineteenth century in the US, some scholars have considered the issue of being or not being a profession as unavoidable in dealing with ethics education. Their way to approach professional ethics embraces the premises of academic professional ethics pioneers, such as US philosopher Tom Beauchamps and Quaker theologian James Childress (Beauchamp and Childress 2001 [1979]). Co-authors of the world's premier medical ethics handbook for students, reedited several times since then, translated into many languages and still in use today, they both have had a great influence on all the academic field of professional ethics. According to them, without any doubt, the concept of profession is necessary to study ethics: "we need a more restricted meaning for the term profession in order to appreciate the context of professional ethics" (Beauchamp and Childress, p. 6). But, other scholars have considered the professional paradigm as inappropriate, useless or parasitic to the discussion.

It has especially been the case in the fields of business and engineering, which are our focus here. Our aim in this chapter is not to participate in this endless controversy over engineering and business being or not being professions, or over the need (or not) of a well-defined concept of profession to discuss ethical issues and to set up ethical education. Our aim is to get a better understanding of the historical development of the relationship between ethics and occupations and/or professions. I believe that it is a relevant goal for ethics research and teaching, especially in a global context, to study the cultural environment into which research and education take place today, but also to study the emergence of the professional paradigm and its relation to local/national issues, historical contingency and theoretical framework.

6.2 Profession As a Multidimensional Controversial Issue

6.2.1 Linguistic Dimension

The task of defining professions has been taken very seriously in social sciences in Great Britain and in the US since the beginning of the twentieth century. The first sub-domain of the academic field called "professional ethics" which has led to the creation of many top level conferences and specific academic journals, was medical ethics. The works of sociologists, like British Alexander Carr-Saunders and Paul Morris and American Talcott Parsons, have generally inspired the theoretical framework of medical ethics, and professional ethics. Carr-Saunders and Wilson stated that the distinguishing mark of a professional was the possession of "an intellectual technique acquired by special training", and that a profession could only be said to exist when there were "bonds between the practitioners, and these bonds [could] take but one shape – that of the formal association" (Carr-Saunders and Wilson 1933, pp. 200–298), but they did not provide a conceptual definition of the profession.

Although Parsons' works and his definition of a profession as the provision of a service, based upon a body of expert, scientific knowledge (Parsons 1968, p. 356) have served as references to many scholars, the search for a conceptual definition of the professions did soon become a problematic endeavor (Goode 1957). Scholars of the professions neither agreed on the list of traits clearly separating the professions from other occupations nor on the list of undisputed professions. Moreover, outside of the English language areas, which were the linguistic context of the pioneers in this field, many scholars have not found it relevant either to study “the professions” or to conceptualize the word “profession”.

David Sciulli, a US scholar of the professions, observed that “not a single continental language either before or after the Second World War developed indigenously a term synonymous with or generally equivalent to the English term ‘profession’” (Sciulli 2005, p. 915). Not referring to the word profession might then depend on the absence of an equivalent term in another language. Sometimes there seems to be one, like the French word *profession*, but it is actually a “fake friend”. Sciulli wrote that French sociologist Pierre Bourdieu considered the very term profession as a manifestation of Anglo-American cultural imperialism (Sciulli 2009, p. 13). Interestingly enough, Pierre Bourdieu and Loïc Wacquant actually used the expression “Anglo-American cultural imperialism” in their work and applied it to several concepts in the paper quoted by Sciulli (Bourdieu and Wacquant 1998). But they did not apply it to the word “profession” in their original French version, maybe (that’s our hypothesis) because it would not be so meaningful for their French readers. On the contrary, they took the concept of profession as an example of Anglo-American imperialism in the English version of their work (Bourdieu and Wacquant 1999), as it might be meaningful to English readers (our hypothesis, again). Actually Bourdieu did not *study* the professions and would rather have used his concept of *champ* (field) to discuss such issues.

6.2.2 Political Dimension

Scholars who study the professions often recall the Latin etymology of the word, with *pro-* meaning « forth », leading to *profess,* which means, “to declare something publicly”. Besides, they often recall the common language opposition between professional and dilettante or novice. Those for whom defining the professions and their distinctive features is relevant also often refer to a conference given in 1915 by Abraham Flexner, which they regard as seminal (Flexner 1915). In this conference entitled “Is social work a profession?”, the US education reformer listed six criteria that he deemed essential in defining the boundaries of a profession. His criteria selection was based on what he designated as the “few professions universally admitted to be such, – law, medicine, and preaching”. Flexner claimed that social work – as well as nursing and pharmacy – could not be seen as a profession but as a “mediating occupation, coordinating the activities of other professions”. On the contrary, “with medicine, law, engineering, literature, painting, music, we emerge from all clouds of doubt into the unmistakable professions”. Flexner’s taxonomy generated many other demarcationist endeavors of the same kind. Also using the trait-approach, British scholars Alexander Carr-Saunders and Paul Wilson started their own historical works on the professions by establishing a list of occupations which, to a greater or lesser degree, came closer to being a profession, i.e. closer, as they wrote, to the "ancient, learned and accepted profession of medicine, law and the ministry and university teaching" (Carr-Saunders and Wilson 1933, pp. v, vii). According to them these occupations had exhibited the same characteristics and patterns which were founded in their origins, nature and activity.

In a paper called "The Flexner myth and the history of Social Work", David Austin, a pioneer in Social Work research in the US, recalled that the 1915 conference was not given to a scholarly audience in a scientific congress. According to him its issue was not a scientific but a political one and the definition of profession given by Abraham Flexner was not the outcome of a concept construction making this conference. It was "a prime example of the extent to which untested social science pronouncements can become endowed with the weight and authority of scientific trust" (Austin 1983, p. 357). In 2001, Austin was the guest editor of a special issue on Flexner's conference, with included a reprint of the conference (Austin 2001). To date, this reprint is the journal's most quoted paper (google scholar, 1240 in 2017), whatever the critics made.

6.2.3 Theoretical Dimension

The disagreement about the relevance of the concept of profession can also be independent of the issues of translation or the difficult quest for its universalization. While the functionalists, who were prevalent among US sociologists in the twentieth century, opted for a definition of the professions that tends to essentialize them around certain core features, the proponents of symbolic interactionism, whose pioneers were also US scholars, saw in the professions activities that were evolving and developing in interactive ways, as a consequence of negotiations with their environment. Everett Hughes wrote, as early as 1951, that what was called a profession in English did not properly describe a body of occupations which should be distinguished from others: "The concept of 'professions' in our society is not so much a descriptive term as one of value and prestige" (Hughes 1994, p. 58). Before Bourdieu, Howard Becker had considered that the word profession matched with the definition given by Ralph Turner to "folk concepts" (Turner 1957), a concept which has a scientific value only as a belief to be analyzed and demands that sociologists take into account the gap separating it from the observable reality (Becker 1962).

Using the concept of profession is not only a question of language (of disposing of the signifier and the signified), it is also a question of theoretical framework. The need of a precise definition is also a question of framework. Thus, there are scholars who never questioned the reality of a specific type of occupations called professions, because they were developing their theories in an Anglo-American context, and have still contested the relevance of searching for a very precise definition of the profession, like Andrew Abbott (1983, p. 856). He wrote later that "Because the term 'profession' is more an honorific than a technical one, any apparently technical definition will be rejected by those who reject its implied judgments about their favorite professions and non-professions. To start with definition is thus not to start at all" (Abbott 1991, p. 18). Michael Prichard, who co-authored one of the classic student textbook on engineering ethics (Harris et al. 1995) wrote in a later book that although "there are no accepted generally accepted definition of 'profession' or 'professional' this should not present a barrier to fruitful inquiry" (Pritchard 2006, p. 4).

Our thesis is that Khurana's project to professionalize business and Davis' design to extend worldwide the concept of profession he coined for engineers, do not need so much to be judged as being ideological, as an expression of imperialism or serving a hidden agenda. They have to be understood in their particular context and analyzed as belonging to a chosen theoretical framework. The difficulty for many non-US scholars to embrace, like Davis and Khurana, but also Childress and Beauchamp or Harris, Pritchard and Rabins, the professional paradigm is neither an accident nor the result of a temporary misunderstanding. The problem is deeper, because the core words used in their specific theoretical framework – and the framework itself – belong to a history of ideas, which is anything but universal. I believe that the controversies around the professional paradigm are worth being studied for anyone interested in professional ethics, because this work might enrich the cross-cultural discussion on the ethical issues of many occupations, regardless of their being considered as professions in some societies or being contested professions like business and engineering. I am aware that the investigation into the story of the professional paradigm I propose, from a Western European point of view – and maybe at times only from a French point of view, is anything but universal.

What has been considered since the end of the nineteenth century in the Anglo-American world as an essential and structuring frontier between the professions and the other occupations is not a natural border. This demarcation is the result of one specific type of evolution of labor organization and industrial relationships, one type among others. In many other regions of the world, even within the Western world, the frontier between occupation and profession does not mean anything. But other dichotomies might have appeared, which are locally very meaningful, like the distinction in France between *cadres* and other categories of employees (Boltanski 1982). The word *cadres* comes from a post-Revolution military term for officers and non-commissioned officers (*cadre* also means frame) and started to designate employed engineers after the 1936 general strikes. Today it designates managers and many highly skilled employees who enjoy a large degree of autonomy, and it has become an unavoidable "social category".

Although not protected by law, it nevertheless has a legal status: an employee who is officially promoted *cadre* by her employer has different employment and pension rights. The usual translation of the term into executive or managers in English does render the term's full social and legal meaning. In a paper written for an English-reading audience, the French sociologist Luc Boltanski explained that although *cadres* was an obvious category for most people, "it [posed] a particular problem for sociology: that of its very existence. The 'native category', peculiar to France, is specific both by virtue of the term that designates it (there is no equivalent in English or in German for instance) and by virtue of the range of occupations it covers. It combines in the same aggregate social groups which are very different from one another in most respect" (Boltanski 1984, p. 469). Unsurprisingly the *cadre* category has been a much more discussed by French sociologists in the twentieth century than the professions (Bouffartige and Gadea 2000). It is believed that an historical investigation can help us understand how the professional paradigm happened to structure the social space as it does today in the US, and thereby help us understand the way professional ethics also developed in various areas.

6.3 A Historical Perspective on Professional Models

6.3.1 The Catholic Model of the Body: The French corps d'état *(The Estate System)*

In feudal times, three orders structured the political life in Western Europe: the clergy (*oratores*), the nobility (*bellatores*) and the working people representing 90% of the population (*laboratores*), who were mostly famers. Each order had its responsibilities, privileges and special honors. This trifunctional organization which has been found in most Indo-European societies (Dumézil 1941) went through a period of crisis in the twelfth century. The living context in Western Europe changed, stimulated by a dynamic revival of a commercial economy, the development of trade, craft and the emergence of medieval universities. A higher consideration was given to labor which had long been despised, and considered a necessary evil tainted with the original sin, because located outside the two upper orders: clergy and nobility.

One of the references which founds the distinction between profession and occupation, which can be named a "sacred-profane" dichotomy after Durkheim (1915 [1912]), is an old opposition between mechanical arts (*artes mecanicae*) which were transmitted within the family or the workshop from master to apprentice or from parents to children, and the liberal arts (*artes liberae*) which were taught in specific places dedicated to the transmission of intellectual knowledge. But this distinction was only one of the several oppositions that structured medieval Europe.

The most fundamental one was between people having an *état* (or *métier,* estate in old English), i.e. having a qualification and belonging to an occupational community, and those without. This estate enabled people to differentiate one another, gave them an identity and distinguished them from the people without any social status, the marginals (Dubar and Tripier 1998, p. 33). But there was not much difference between the mechanical *métier* of those who made and sold their work within the crafts and the liberal *professions*, made up of intellectuals trained in the liberal arts and later getting a specialization, and whose services could be paid for (like medical practitioners or lawyers). Actually, all those who mastered an art whether acquired through apprenticeship or learnt through formal teaching were gathered in the same type of organizations. In France, these groups were called, until the French Revolution, *corps* (from the Latin *corpus* meaning body, translated by the generic term *guild* in English since the nineteenth).

During the classical Middles Ages, civilian or ecclesiastic authorities in several Western European countries gave teachers the monopoly of conferring degrees. Masters and students gathered to pursue freely research and teaching. This gathering called *universitas* was soon recognized as an official scholastic *corps*. The master of *arts* degree became the equivalent of the masterpiece that enabled the *compagnon* (journeyman) to apply for a position of master in a *corps d'état* (craft guilds) (Le Goff 1980, p. 317). The development of the medieval university came from the need for skills in computation and reading, not for the clergy only but also to support the development of economy. Its vocational dimension, much discussed nowadays, was very present then: universities were probably "more vocationally-orientated in the Middle Ages than at any other time in their history" (Rospigliosi et al. 2016, p. 193). The research-oriented Humboldtian model, which is dominant today in many countries, is a concept of holistic academic education that emerged in the early nineteenth century only in Germany.

The Dutch historian William Sewel identified, beyond the various types of *corps* in medieval society (called *corps*, *ordre* and *communauté,* in French), the same "corporate idiom" i.e. "an expression of the *corps* as a moral community". Among their common traits, one was more specific to France, the legal recognition of the *corps*: they were organized by the State and the king alone was the guarantor of the universal law. The royal patent established the estate as a sworn body (*état juré* or *métier juré* whose status was called *jurande*) and transformed the community into a legal person, a subject of the king (Sewell 1980). Like Christ, the monarch had a double body: a natural (actual) one and a corporate (fictional) one, which was the aggregate of the king's subjects.

This model of the double nature body was rooted in the Catholic theology and the Christological dogma of the two natures of Christ. It also fitted the political doctrine of the time, which sacralized secular power. This model flourished better within a centralized vision of political life, already present in feudal times and which strengthened over time in France, a country characterized by a high degree of administrative and political centralization. The expression "political body" (*corps politique*) and "social body" (*corps social*) became very important in the political discourse of the Enlightenment and of the French Revolution.

The development of commerce and trade, the creation of the royal manufactories and the expansion of liberal ideas started to set out the end of the corporative model before its destruction by the Industrial Revolution and its abolition by the French Revolution and the 1791 law (Castel 1995). A new model of labor had already appeared since the fifteenth century with wealthy merchants in Flanders, England and Northern Italy organizing production chains in order to control the entire production process (Dubar and Tripier 1998, p. 30). Later on, Colbert, a finance minister of King Louis XIV created in the seventeenth century the Royal glass and tapestry manufactories as public commercial and industrial properties. They were granted a royal patent, which gave them an industrial monopoly to develop a strong national industry. In those manufactories co-existed the social functioning and stratification of the corporative model and new exemption rules meant to free the labor. Simultaneously, the first *Grand corps d'Etat* (with a capital E) were created in France.

Although a kind of proto-*Grand corps* had been organizing the corps of lawyers since the fourteenth century (Karpik 1999, p. 32), Colbert established this model as a typical French institution, not founded anymore on the transmission of traditions from master to apprentices, but based on science and rationality. The first two he created were engineering corps: a civil one, the *Corps des Ponts et Chaussées* (related to roads and bridges) founded in 1716, and a military one, the *Corps du Génie Maritime*. Others followed, administrative as well as technical ones, like the *Corps des Mines*. The distinction between *Grand Corps* and the other *corps de l'Etat* (still capital E), like the early *corps du Génie* created by Vauban in 1690, has always been a question of prestige and reputation only, two characteristics which are variable and subjective. Still today, there is no legal definition of what is a "*Grand*" corps.

When the *Revolution* took place, the corporative model was already weakened. The new society was not compatible with the existence of intermediary *corps* between the State and the citizens who were not "subjects" of the king any longer. All forms of *corps* were abolished in 1791, and Napoleon's armies disbanded them in most of the continental nations that they occupied during the next two decades. The university was abolished, as well as the faculty of medicine and the general hospital in the name of free exercise of medicine; the Catholic Church lost its privileges. But while the *corps de métiers* (also called *corps d'état,* crafts guilds) disappeared, the administrative *corps de l'Etat* organizing state employees have survived until today.

What today is still called *Grands Corps* (Conseil d'Etat, Cour des comptes, several General Inspections, and also several technical Grands Corps) became major institutions in the French society. Reluctantly, Napoléon re-organized the structuration of a few liberal professions such as the C*ompagnies des notaires* and the *Bureau des avocats* (lawyers) with a state-controlled registration and codes of ethics without any force of law (Karpik 1999). Medical doctors who had embraced the anti-corporation and liberal ideas of the *Révolution* were organized into an Order in 1941 only, in the troubled political context under the Vichy Government: actually, 9 of the 16 actual French orders were created and reorganized between 1941 and 1947. Their status was clarified by a decision made by the State Council (*Conseil d'Etat*) in 1961, making them private organizations in charge of a public service mission. The latest oders to be established were created in 2006 (nurses, physio-therapists and chiropodists).

After the *Révolution*, French historians coined the word *corporation* (still in use today) as a generic term to designate the various types of *Ancien Régime corps* that had just been abolished. Unlike the English "corporation" it has never designated, any society or economic entity. Despite the destruction of the *corps*, the French expression *corps d'état* (with a small "é") still designated in the middle of the nineteenth century a community of individuals engaged in the same activity. Nowadays it is used only in the field of construction where an *entreprise tout corps d'état* is an all-trade company. The word "corporatism", also coined in the nineteenth century designates a political ideology, unknown for a long time in the US, which developed at the end of the nineteenth century among French and German Catholic leaders whose goal was to find a middle way between liberalism and socialism (Wiarda 1996). The word has taken on a pejorative connotation and become a synonymous of the defense of private interests against the overall community interest.

6.3.2 The Collegial Model of Brotherhood in Germanic Law and Puritan Ethics

The generic term chosen by English historians to name what is called *corps* in French was also coined in the nineteenth century, but the translation is not accurate because "guild" designates crafts guild as well as the older religious non-professional guild, but also merchants guilds (still called *guildes* or *hanse* in post-Revolution France after their abolition). While the word *corporation,* made out of the oldest term *corps,* had clear Catholic origins and suggested an analogy between the king's body and Christ's body, the term *guild* conveys a very different connotation and comes from a very different etymology. Also spelled *gild*, it probably derives from the Anglo-Saxon root "geld" (to pay, contribute). The noun form of geld meant an association of persons contributing money for some common purpose; another etymology of *geld* is "to sacrifice, worship" (Richardson 2008). The first guilds, whatever their spelling, seem to have existed early in the history of western continental Europe: they were found for instance in the laws of Ina, king of Wessex in the seventh century (Stanley Jevons 2001 [1887]). They were formed for religious and social purposes (neither professional nor commercial). Historians also identified "firth" (peace) guilds operating in the medieval English towns. Contrary to the legally recognized French *corps d'état,* those guilds were voluntary in character. The most widely accepted theory among historians originates this model in pagan traditions of solidarity developed around sharing food and drinks (*convivium*) and mutual protection and defense in a spirit of revenge, while the *corps* might be a kind of survival of the Roman Empire's *collegio.*

The sociologists Claude Dubar and Pierre Tripier in their *Sociologie des professions,* the first French academic book with such an explicit title -, which is a landmark in this field of scholarly research in France (Dubar and Tripier 1998), identified an alternative to the Sewell corporative model. They found its best formulation in the work of German historian Otto Von Gierke on German cooperative Law (*Genossenschaftsrecht*) (1868, 1872, 1881). The authors chose the word *confrérie* (confraternity) to name this model whose roots are to be found more in the Scandinavian and Saxon worlds than in the regions influenced by the Roman Empire, like the south of France, Italy or Spain. They founded this alternative model on an analysis of several types of European organizations sharing similar traits.

In this model, the "profession" is considered as a self-governed community of equals in the same occupation. Access to the association is free and voluntary. An oath constitutes the confraternity of members who share the same values and are personally engaged. Decisions are based on consensus and do not take into account any outside or superior authority. Members have rights and duties, such as defending the group against outside attack. There is a "code of ethics" (actually bearing another name) including a moral discipline. The profession is understood as a personal vocation, a calling to follow God's will. There are a few common points between Sewell's "corporate model" and the "collegial one" coined by Dubar and Tripier, such as the existence of an oath and of a code of ethics, but their logics are deeply different from one another. In the *corps*, the oath resembles the monastic vows (to be obeyed rather than professed) and the code of ethics is more like an *esprit de corps*, an ethos, rather than a moral discipline meant to prevent an excessive status and power imbalance (Dubar and Tripier 1998, p. 39).

The first example developed by Dubar and Tripier is the "German version" of their alternative model. According to Von Gierke, Germany was characterized from the thirteenth to the sixteenth century by the creation of confraternal guilds, with a strong sense of egalitarian ethos, rooted in the oldest German traditions. Those guilds of monks, noblemen or craftsmen were in charge of their own affairs in their own territory. They organized a social order founded on the autonomy of local organizations in free towns, which was later codified in Germanic law. Princes were elected and gathered in a collegial council. In time of peace, the State did not have a unique head. In time of war, they chose among themselves the peer who would take over the high command. Some German people had a king, but also a prince elect: this model based on the freedom of the people and the sovereignty of the authority was as far from the Roman Republic as from the absolute monarchy. Germanic law was not imposed from above by the prince but derived from the practices and customs of the citizens.

Although this model of regulation had to face absolute monarchy in Prussia in the seventeenth century for instance and the inclusion of Roman Law, Gierke still identifies in the nineteenth century traces of this confraternal model in the constitution of the *Länder*. He also sees it in the proliferation of community education organizations, the which development of which faced more difficulties in France. This alternative model did not develop only in countries with Germanic Laws but also in other areas sharing a common ethos. The Protestant culture, with its defiance of established authorities and its valorization of an egalitarian ethos, has been particularly favorable to the development of this model, as well as a context of autonomous communes which developed independently from nobility, such as the German free-cities.

The second example developed by Claude Dubar and Pierre Tripier is the puritan community. The Puritans were religious dissenters who thought that Anglicanism, the *via media* between Protestantism and Catholicism adopted for personal reasons by the King of England in 1534, was too similar to Catholicism and needed to be purified. When they realized that James I, king of England (1603–1625), would not reform Anglicanism, they joined the Great Migration to the New World where they brought with them a collegial, self-organized model which had a great influence on the shaping of North America. They also founded a religious *état d'esprit* marked by a sense of individual responsibility for each Christian in front of God, without channeling through a clergy endowed with a sacramental authority. For the Puritans, work was a "key to order and the foundation of all further morality" (Walzer 1965). And this inner-worldly ascetic attitude attributed by Max Weber to the first Calvinist entrepreneurs (Weber 1930 [1904–1905]) was actually the ethos of the whole community (Walzer 1965). According to the Puritans and also the Quakers, both following Martin Luther and John Calvin's ideas despite their different view on religious freedom, the Christian calling was not a condition of one's birth but a sacred task to select for oneself and a path toward perfection in one's earthly journey.

English casuist William Perkins was the most influential English theologian of the late sixteenth and early seventeenth centuries and wrote three treatises on vocations. According to him beggars' idleness was considered a soul-disorder, but the monkish kind of living was also damnable because it was not profitable for some society or body (Perkins 1626 [1605], p. 756). Perkins also made a distinctions between two sorts of calling: every Christian had a general calling, but few of them had a particular one which stood higher because it was "of the essence and foundation of any society": in the family, there was the calling of the master (as opposed to the calling of the servant), of the husband and the father (versus the calling of the child) and in the Commonwealth, the calling of the magistrate, church minister and physicians (versus the calling of the subject) (Perkins 1626 [1605], p. 758). This distinction between general and special callings can be seen as another root of the nineteenth century English language distinction between profession and occupation, less concerned with the nature of the knowledge (liberal or mechanical) than with a religion-founded commitment to community.

The contemporary English historian Rosemary O'Day detected in Perkins's discussion of particular vocations "several elements which later became associated with the learned profession" (…) At the root of this teaching was the belief that the call to profess and perform such a service came directly from God and that the accountability of the professional was to God" (O'Day 2000). Her thesis is that sociologists of the professions did not take enough into account the real history of the occupational groups, their actual activities and the inner differences between them because "they have been too readily absorbed by the model that they have constructed, which can bear little resemblance with the individual cases". According to her, they looked into the past for the origins of the present instead of understanding professions as historical constructs.

After quoting George Fox, the founder of the Religious Society of Friends (Quakers), she began her introduction discussion it: "George Fox *assumed* the existence of three learned professions – the clergy, the lawyer and the physicians" (our emphasis). Then she explained how contemporary historians and sociologists have derived the feature that they attributed to the profession from their observations and views of the nineteenth and twentieth century occupations called "professions" in North America. "Features that are seen distinctive in todays' world (such as autonomy or flexibility of work practices) seemed unremarkable in the 16th and 17th centuries" (O'Day 2000). She even remarked that if the "*continuum* method" was used to measure how closely an occupation matched the characteristics of the twentieth century concept of professionalization, medicine should be considered as the last of the ancient professions to "be professionalized". Andrew Abbott also wrote that "English barristers do not necessarily train in university but rather by apprenticeship and eating dinners 'in hall.' American clergy do not generally have codes of ethics …. Yet both groups are unmistakably professions" (Abbott 1988, p. 8).

The peculiar occupations which were considered, in Perkin's context, as answers to special callings, because they were supposed to serve an "essential function for society", are what Flexner named the "few professions universally admitted to be such" (Flexner 1915) and sociologists Carr-Saunders and Wilson, the "ancient, learned and accepted profession" (Carr-Saunders and Wilson 1933). Their members, the professionals, have later on been described as pursuing "higher aims" following the functionalist theory developed by Parsons, but even more by the early ethicists such as Edmund Pellegrino. A major US pioneer of bioethics, Pellegrino was the world second lay president of a Catholic university. He considered that the professionals' claim "[lied] less in their expertise than in their dedication to something other than self-interest while providing their service". According to him, these occupations "are in this sense "professed" i.e. publicly committed to the welfare of those who seek their help. They thereby become ethical enterprise" (Pellegrino 2002, pp. 378–379). This is close to Michael Davis' position concerning engineers, their profession and their ethics.

6.4 Beyond Misunderstanding

6.4.1 Western Scholars vs. Western Scholars

In 2009, I received the reviewers' comments on a paper proposed for publication after the Delft Workshop of Philosophy and Technology (which initiated the actual Forum of Philosophy, Engineering and Technology) (Didier 2010). One of my anonymous reviewers wrote: "At first reading, I was convinced that the author could not possibly be serious. "Engineering ethics was invented in the United States"? What nonsense! Engineering ethics has always existed as engineers have made moral decisions. What we have done during the last half century is to begin to articulate and examine these decisions. So my first reaction was that the author was either ill-informed, or joking. But as I read the rest of the paper, it became clear that the author was not ill-informed, and *he* was not joking, but had something interesting to say to the rest of us *who have always assumed that what we were talking about made perfect sense to others.* I would lean toward accepting this paper, but I wish I could have been in the audience, in the front row, ready to pounce!)" (our emphasis). This particular comment on my work is actually what led me to explore more deeply the history of the professions and language issues around professions.

I knew from reading *Sociologie des Professions*, a book co-authored by Claude Dubar and Pierre Tripier which marked the renewal of this long-abandoned field in

France, that the use of the term profession in French was different, and especially more polysemic than its English equivalent (Dubar and Tripier 1998, p. 7). I had understood that in the United States and also in other English-speaking countries, the idea that some occupations were distinct from others had gradually become a social norm, but I did not imagine, for instance, that the *cadre* category would not mean anything to most of them. For some US scholars, the distinction between professions and occupations is founded on the disinterestedness and dedication of the professionals to the good of the community. For others, it is based on prestige or on the professionals' capacity to constitute closed labor markets or to impose a socially constructed distinction as essential. Whatever the origin of this distinction, it had become an indisputable legal reality in the US and some other regions of the world.

While I very often have used the term *profession* as a synonym for a trade, as is customary in French (Dubar and Tripier 1998), I have become aware that the definition of profession could be more specific in another language than mine. For instance, the contemporary Oxford English-language dictionary defined profession as "a type of job that needs special training or skill, especially one that needs a high level of education". I should have specified before "as is customary in French language as it is used in France" since the Quebec conception of what constitutes a *profession* – and the use of the word – is much closer to the English and US definition and the Parsonian ideal-type than in France (Dussault and Borgeat 1974). Members of the occupations are called in Quebec French *gens de métiers* (which sounds like a denomination from the Middle Ages for a French person) and are grouped in associations whereas members of the 46 *professions* are organized in *Ordres professionnels.*

I have long considered the Anglo-American concept of profession of little use to study the means to develop an ethical sensitivity during the training of future French engineers. The international meetings and conferences I have attended, especially the Workshops on Philosophy and Engineering followed by the Fora on Philosophy, Engineering and Technology have made me believe that scholars coming from other countries than France, such as Japan, for instance, could face the same problem. The Institution of Professional Engineers founded in 1951 adopted a code of ethics in 1961, but because of the general lack of interest in engineering ethics, this code was not widely promoted. The explanation of the Japanese professor Jun Fudano and US ethicist Heinz Luegenbiehl is that "the concept of engineering as a profession is unequivocally absent in Japan, most likely because the development of engineering was dominated by the state and industry, rather than by public forces" (Fudano and Luegenbiehl 2005).

Moreover, the aim to professionalize management as a means of moralizing business, through the writing of codes of ethics and the setting up of a license to exercise management is also unlikely to be heard of in France, as I have argued in my research on whistleblowing for engineers (Didier 2007) and whistleblowing policies (Didier 2011). And, France is undoubtedly not the only country where this way to deal with ethical issues would encounter a form of resistance, which would not merely be the expression of delay or conservatism.

6.4.2 A Response Quest

Several explanations have been given about the importance of the professional paradigm in the United States. US historian Burton Bledstein traces the fascination of the middle classes for the professions back to the beginning of the nineteenth century (refusal of any form of inherited privileges, power to acquire social wealth and consideration if one tries to develop his/her capacities so as to increase his/her social utility). According to him, "for middle-class Americans, the culture of professionalism provided an orderly explanation of basic natural processes that democratic societies, with their historical need to reject traditional authority, required. Science as a source for professional authority transcended the favoritism of politics, the corruption of personality, and the exclusiveness of partisanship. (…) The culture of professionalism was at the basis of the habits of thinking and acting of the middle class and that most American people of the 20th century have taken for granted that any modern and intelligent person shall organize its private and public attitudes toward this value" (Bledstein 1976). Our historical journey through the French *corporations* and the collegial model, and into the impact of the Reformation on the conceptualization of specific callings, its extension in the US sociology of the professions and in the emerging academic field of professional ethics aimed to open up new avenues for research.

Our research actually highlighted more ancient roots of the professional ideal and the role of the political and religious contexts in which it grew up.

Concerning the religious background, Pierre Tripier considers that "behind the affirmation of Parsons that the more a society modernizes, the more it professionalizes; the more it becomes professionalized, the more it pacifies, there would not only be the family picture proposed by Durkheim in the second preface to *De la division du travail social* (Durkheim 1984 [1902]). There would also be the cultural form left by Puritanism, which legitimates the profession's privileges (its ability to refuse the laws of the market and democracy) by the right of everyone to trace a path in relation to his propensities and the demands of his conscience, and the benefits that would accrue to the community" (Tripier 1998).

Concerning the political context, the American professions appear to embody what Alexis de Tocqueville called the "intermediary bodies". The French political scientist observed that in a highly decentralized and individualistic nation like the United States, individuals tended to gather in multiple associations that stood between them and the State. They concurred toward the integration of individuals, limited the power of the state and defended individual freedoms (de Toqueville 1838 & 40 [1835 & 40]). More recently, US sociologist Eliott Freidson opposed the hierarchical states (where an important administrative apparatus imposes dirigist orientations) to the coordinating States (whose action is essentially reactive and coordinating initiatives of civil society groups). According to him, professions have found their best conditions for self-fulfillment in regions where the State did not interfere in their functioning and where they did not experience competition from other institutions entrusted with the common good (Freidson 2001).

German social psychologist Harald Mieg contrasted the countries were professions developed "from within" and gained a strong social status like England and the US and a Continental pattern of professionalization where the main occupation had been shaped "by above". He gives as an example France and Germany (Mieg 2008).

I discussed a lot in this chapter the various understanding of what it meant to be a profession, and how this debate could contribute to a better understanding of the status and stake of ethics in various occupations and/or professions and in the higher education preparting to them in a global world. There would also be much to say about the various understandings of the term ethics across cultures, and the impact of religion on ethics discussion, but this was not our goal here. Besides, others scholars have done it already.

Today, one of the major issues in the academic field of business ethics in a global world, is its secularization. Business ethics in the US – where it was "invented" like engineering ethics-, has actually largely been until now an expression of religion, an attempt "to marry the realities of business practice with the moral teaching of Christianity" (Mees 2012). According to Bernard Mees, "even in the less publicly devout European West, much of the recent discourse of business ethics has remained decidedly Christian in its formulation". Already in 1987, US philosopher Richard T. De George, one of the founders of the study of business ethics also described the contributions of the Christian religion, both Catholic and Protestant, as primary one in the field (De Georges 1987). Daniel Callahan, co-founder in 1969 of the Hastings Center, the world's first bioethics research institute, which was instrumental in establishing bioethics as a field of study, stated in 1990 that "the most striking change over the two past decades or so [had] been the secularization of bioethics" (Callahan 1990, p. 2). But this autobiographical reflection where Callahan acknowledged the diminishing relevance of religion in his own life, he also wondered about the risk for pluralism which was celebrated as a moral achievement to become "oppressive if it is not open to the insights of particular traditions and communities".

6.5 Conclusion

The distinction between occupation and profession, which was central in our reflection here, does not belong to the cultural matrix of many regions outside the USA, England and some Commonwealth countries. In France, for instance, the social space is structured around a separation between the employees and the non-wage-earners, with on the one hand the members of the liberal professions and the self-employed, and on the other the employees of the State, called *fonctionnaires*. There are also strong hierarchies within each group: one is a member of a more or less prestigious *corps d'Etat*. Some employees are also *cadres*. Some have the privilege of having a *Contrat à Durée Indéterminée* (CDI) which is an open-ended employment contract which is very protective for employees, while some do not have this privilege. Status can overlap: a doctor may be an employee in the private sector, or in the public sector, or self-employed and paid on a fee-for-service basis. But in any case she is today in France a member of a regulated profession managed by an order.

The equivalent of the American professions that Davis wants to apply to engineers all over the world or which Khurana wants to re-establish for businessmen cannot be found in France neither in todays' *professions libérales* (exercised under an independent status which does not say anything about higher aims to be pursued, a skiing instructor belongs to a liberal profession as well as a translator-interpreter), nor in the regulated professions (the French *bistrotiers* who must have a license are considered as members of a regulated profession in the European sense).

Our comparative investigation into words, culture and professional arrangements does not allow us to say what professional or occupational ethics for engineers and business people should be. However, it recalls us that the concept of profession is a theoretical concept that can serve the scholarly work and ethics education in some parts of the world but not "everywhere". It also recalls us that the project to build a more equitable society where engineers and managers – whether regarded as *cadres*, professionals or *gens de métiers* – would take their share according to their role, position, knowledge and power, cannot be thought of without seriously studying the relations between individuals, the political regime and the moral insights of the religions and philosophies, which have shaped the local culture. It invites us to increase our awareness of the explicit and implicit relations between the formulation of the professional ethics discourse and Christian world views and anthropology.

The USA where profession is the current paradigm of most scholarly works on occupational ethics is a young state born on an individualistic basis without the legacy of medieval feudalism and *Ancien Régime* corporatism that continental Western Europe (and not so much England) had experienced for nearly a thousand years, with the estate system and the tradition of corporate privileges. People in what has become the USA, created institutions and developed a culture, which has many things in common with Western European countries, compared with Africa or Asia. But the industrial relationships, the relationships between the State and the citizen, and between religions, the State and the people, have many singularities when compared with Old Europe, which again is far from being uniform in that respect. Contrary to what Michael Davis believes, sociologists – and historians too – could help us understand better those differences, which have taken a lot of energy and writing and brought so much misunderstanding. Theoretical disagreements are sometimes founded on diverse ways to analyze and interpret the observed reality. But when the discussion tries to take place in the global world in a multicultural environment, what looks like a disagreement of explanation can also be founded totally or partially on a misunderstanding. Most probably philosophy can be relevant to discuss engineering and business ethics but as a major US philosopher of twentieth century wrote, "it is not more relevant than many other fields of study (such as history, law, political science, anthropology, literature, and theology)" (Rorty 2005).

The engineers and managers' ethics may not be determined by a sacred "status" that would be reminiscent of a Christian-type of calling. It might have to be founded on their expert knowledge (what they know as graduate engineers and managers which others cannot), their position in the socio-economic system (what they can see from where they stand which others cannot), their power (what they can do individually and collectively which others cannot). Although engineers and managers do not have exactly the same expert knowledge, power and position, they share many traits, especially the type of organizations for whom they work as high skilled employees (I would say *cadres* in French). To whom are they ready to sell their skills? And on which conditions?

There are many ways to distinguish engineers from managers: they do not have the same training, might not always have the same social and cultural background and careers expectations, do not have the same kind of jobs in general, and all this varies from one country to another. Still engineers and managers have much in common and many good reasons to build together, and with other members of society, their ethical sensitivity, their ability to discuss ethical issues, to think and have a say about the habits, rules, hard and soft-laws regulating their practice. Ethics education is neither a mere question of transmitting a corpus of standards of a defined profession. If teaching ethics was like preaching, it would be an easier task. But as Immanuel Kant believed that it was impossible to teach philosophy, it might be impossible to teach professional ethics: "[t]he youth who has completed his school instruction has been accustomed to learn. He now thinks that he is going to learn philosophy. But this is impossible, for he ought now to learn to philosophize" (Kant 2011 [1765]). But following Kant, we can think that it is possible to learn to practice ethical reflection, to be able to raise ethical questions in situation with many others and take into account its social, legal, but also cultural, political and religious dimensions and to aim "at the 'good life' with and for the others, in equitable institutions" (Ricoeur 1991).

References

Abbott, A. (1983). Professional ethics. *American journal of sociology, 88*(5), 855–885.

Abbott, A. (1988). *The system of professions: An essay on the division of expert labor*. Chicago: Chicago University Press.

Abbott, A. (1991). The future of professions: Occupation and expertise in the age of organization. In D. N. DiTomaso & S. Bacharac (Eds.), *Research in the sociology of organizations* (pp. 17–42). Greenwich: JAI Press.

Austin, D. (1983). The flexner myth and the history of social work. *Social service review, 57*(3), 357–377.

Austin, D. (2001). Guest editor's foreword. *Research on social work practice, 11*, 147–151.

Beauchamp, T. L., & Childress, J. (2001 [1979]). *Principles of biomedical ethics*. Oxford: Oxford University Press.

Becker, H. S. (1962). The nature of a profession. In N. B. Henry (Ed.), *Education for the professions. The 61st yearbook of the NNSE* (pp. 27–47). Chicago: University of Chicago Press.

Bledstein, B. J. (1976). *The culture of professionalism. middle class and the development of higher education in America*. New York: Norton.

Boltanski, L. (1982). *Les cadres. la formation d'un groupe social*. Paris: Editions de Minuit.

Boltanski, L. (1984). How a social group objectified itself: "Cadres" in France 1936–1945. *Social Science Information, 23*(3), 469–491.
Bouffartige, P., & Gadea, C. (2000). *Sociologie des cadres*. Paris: La Découverte.
Bourdieu, P., & Wacquant, L. (1998). Sur les ruses de la raison impérialiste. *Actes de la Recherche en Sciences Sociales, 121–2*, 109–118.
Bourdieu, P., & Wacquant, L. (1999). On the cunning of imperialist reason. *Theory, Culture and Society, 16*, 41–58.
Callahan, D. (1990). Religion and the secularization of bioethics. *The Hastings Report, 20*(4), 2–4.
Carr-Saunders, A. M., & Wilson, P. A. (1933). *The professions*. Oxford: Clarenton Press.
Castel, R. (1995). *Les métamorphoses de la question sociale. Une chronique du salariat*. Paris: Fayard.
Davis, M. (1997). Is there a profession of engineering? *Science and Engineering Ethics, 3*(4), 407–428.
Davis, M. (2008). Is engineering a profession everywhere? *Philosophia, 37*, 211–225.
De Georges, R. T. (1987). The status of business ethics. *Journal of Business Ethics, 6*(3), 201–211.
Toqueville, A. de (1838 & 40 [1835 & 40]). *Democracy in America* [De la démocratie en Amerique] (H. Reeves, Trad.). London: Saunders & Otley.
Didier, C. (2007). Questioning whistleblowing as a response to the engineer's dilemma of loyalty. In S. H. Christensen, M. Meganck, & B. Delahousse (Eds.), *Philosophy in engineering* (pp. 263–276). Aarhus: Academia.
Didier, C. (2010). In A. Goldberg & I. Van de Poel (Eds.), *Professional ethics without a profession*. Dordrecht: Springer.
Didier, C. (2011). L'alerte éthique. In N. Postel, D. Cazal, F. Chavy, & R. Sobel (Eds.), *La RSE, une nouvelle régulation du capitalisme* (pp. 209–220). Lille: Presses universitaires du Septentrion.
Dubar, C., & Tripier, P. (1998). *Sociologie des professions*. Paris: Armand Colin.
Dumézil, G. (1941). *Jupiter Mars Quirinus. Essai sur la conception indo-européenne de la société et sur les origines de Rome*. Paris: Gallimard.
Durkheim, E. (1915 [1912]). *The elementary forms of religious life* [Les formes élémentaires de la vie religieuse. Le système totémique au Australie]. (J. W. Swain, Trad.) London: G. Allen and Unwin.
Durkheim, E. (1984 [1902]). Some remarks on professional groups, preface to the 2nd edition. In *The division of labor in society* [De la division du travail social] (W. D. Halls, Trad., éd. 1ere ed. 1893). New York: Macmillan.
Dussault, R., & Borgeat, L. (1974). La réforme des professions au Québec. *Canadian Public Administration, 17*(3), 407–422.
Flexner, A. (1915). Is social work a profession? *School and Society, 26*, 901–911.
Freidson, E. (2001). *Professionalism, the third logic: On the practice of knowledge*. Chicago: University of Chicago Press.
Fudano, J., & Luegenbiehl, H. C. (2005). Japanese perspectives. In C. Mitcham (Ed.), *Encyclopedia of sciences, technology and ethics* (Vol. 2, pp. 1071–1074). Detroit: MacMillan Reference.
Goode, W. J. (1957). Community within a community: The professions. *American Sociological Review, 22*(2), 194–200.
Harris, C. J., Pritchard, M. S., & Rabins, M. J. (1995). *Engineering ethics*. Wadsworth: Cases and Concepts.
Hughes, E. C. (1994). In L. Coser (Ed.), *On work, race and the sociological imagination*. Chicago: University of Chicago Press.
Kant, I. (2011 [1765]). On his announcement of the programme of lectures for the winter semester 1765–1766. In P. Guyer & P. Frierson (Eds.), *Kant: Observations on the feeling of the beautiful and sublime and other writings* (P. Frierson, Trad., pp. 249–260). Cambridge: Cambridge University Press.
Karpik, L. (1999). *French lawyer: A study in collective action 1274–1994*. Oxford: Oxford University Press.

Khurana, R. (2007). *From higher aims to hired hands: The social transformation of American business schools and the unfulfilled promise of managements as a profession*. Princeton: Princeton University Press.

Khurana, R., & Nitin, N. (2008). It's time to make management a true profession. *Harvard Business Review, 86*, 70–77.

Le Goff, J. (1980). Les métiers et l'organisation du travail dans la France médiévale. In M. François (Ed.), *Encyclopédie de la Pleïade. La France et les français* (1st ed., 1972,. pp. 310–337). Paris: Gallimard.

Mees, B. (2012). Secularizing business ethics. In *Proceedings of the fourth annual conference of Academic association of historian in Australia and New Zealand business schools* (pp. 1–19). Sydney: AAHANZBS.

Mieg, H. A. (2008). Professionalisation. In F. Rauner & R. Maclean (Eds.), *Handbook of technical and vocational education and training research* (pp. 502–508). Dordrecht: Springer.

O'Day, R. (2000). The professions in early modern England. In *Servants of the commonweal* (pp. 1450–1800). Harlow: Pearson Education Limited.

Parsons, T. (1968). Professions. In D. Stills (Ed.), *International encyclopedia of the social sciences* (Vol. 12, pp. 536–547). New York: Collier-McMillan.

Pellegrino, E. D. (2002). Professionalism, profession and the virtues of the good physician. *The Mount Sinaï Journal of Medicine, 69*(9), 378–384.

Perkins, W. (1626 [1605]). *A treatise of the vocations. or callings of mel (men) with the sorts and kindes of them and the right use thereof (of them)* (1st ed., Cambridge 1605). London: John Legat.

Pritchard, M. (2006). *Professional integrity: Thinking ethically*. Lawrence: University Press of Kansas.

Richardson, G. (2008). Medieval guilds. In R. Whaples (Ed.), *EH.Net encyclopedia*. March 16, 2008. URL http://eh.net/encyclopedia/medieval-guilds/

Ricoeur, P. (1991). *Soi-même comme un autre*. Paris: Seuil.

Rorty, R. (2005). *Is philosophy relevant to applied ethics?* Society of Business Ethics Annual Meeting.

Rospigliosi, P., Bourner, T., & Heath, L. (2016). University's engagement with vocationalism: Historical perspective. *International Journal for Research in Vocational Education and Training, 3*(3), 185–211.

Sciulli, D. (2005). Continental sociology of professions today. *Current Sociology, 53*(6), 915–942.

Sciulli, D. (2009). *Professions in civil society and the state: Invariant foundations and consequences*. Leiden: Brill.

Sewell, W. (1980). *Work and revolution in France: The language of labor from the old regime to 1848*. Cambridge: Cambridge University Press.

Stanley Jevons, W. (2002 [1887]). *The state in relation to labor*. New Brunswick: Transaction Publishers.

Tripier, P. (1998). De l'éthique puritaine au "voleur professionnel": discussion sur la vocation. In R. Bourdoncle & L. Demailly (Eds.), *Les professions de l'éducation et de la formation* (pp. 27–38). Lille: Septentrion.

Turner, R. (1957). The normative coherence of folk concepts. *Research Studies of the State College of Washington, XXV*, 127–136.

Von Grieke, O. (1868, 1872, 1881). *Le droit allemand de la confraternité.* Berlin.

Walzer, M. (1965). *The revolution of the saints. A study in the origins of radical politics*. Harvard: Harvard University Press.

Weber, M. (1930 [1904–1905]). *The protestant ethics and the spirit of capitalism* (T. Parsons, Trad.). London: Allen and Unwin.

Wiarda, H. (1996). *Corporatism and comparative politics. The other great Ism*. London/New York: Routledge.

Christelle Didier BS in Electrochemistry Engineering, MA in Education, PhD in Sociology from Ecole des Hautes Etudes en Sciences Sociales (EHESS) Paris. From 1993 to 2013 Assistant Professor at Catholic University of Lille, France, Ethics Department. Assistant Professor, Université de Lille, Département des sciences de l'éducation UFR DECCID. Co-author of *Ethique industrielle* (DeBoeck, Brussels, 1998) and *International Perspectives on Engineering Education* (Springer 2015); author of *Penser l'éthique des ingénieurs* (PUF, Paris, 2008) and *Les ingénieurs et l'éthique. Pour un regard sociologique* (Hermes, 2008). She has published many articles on ethics and social responsibility in the engineering profession and education, and on the engineering profession's values (from interviews and extensive surveys). Research areas: engineering ethics and values, including historical, cultural and gender perspective, sustainable development and corporate social responsibility, social responsibility.

Part II
Engineering and Business Ideologies Past and Present

Chapter 7
Industry Versus Business: Thorstein Veblen's Deconstruction of the Engineering-Business Nexus

Steen Hyldgaard Christensen and Bernard Delahousse

Abstract One of the most controversial claims ever made on the engineering-business nexus was put forward by Thorstein Veblen (1857–1929) in his 1921 book *The Engineers and the Price System,* in which he argued that the engineers would have the potential to become a revolutionary class in America. His claim fundamentally questioned, if not entirely rejected, the rationale of a nexus between engineering and business. Veblen explored the cultural contradictions of capitalism (The formulation is borrowed from the title of Daniel Bell's 1976 book *The Cultural Contradictions of Capitalism* published with BasicBooks and reprinted in 1996 with the same publisher) (the price system) in terms of a contradiction between industry and business. From an anthropological perspective he traced this contradiction to the residual habits of primitive societies. By juxtaposing engineers to the 'pecuniary class' Veblen aimed to explore a possible candidate movement such as the one led by progressive engineers with the potential to delegitimize the prevailing business ideology for a final socialist overturn. However interpretations of *The Engineer*s *and the Price System* have varied. The purpose of this chapter is to argue in favor of a reinterpretation of *The Engineer*s *and the Price System* by addressing a number of issues and claims in the literature on Veblen that we find problematic. In so doing, after an introductory framing of our argument, we will first zoom in on Veblen's industry-business dichotomy and his theory of capitalism, the theoretical backdrop for his early as well as his later treatment of engineers. Second we shall analyze *The Engineers and the Price System* in the light of four interpretive key recognitions. Third we present Veblen's Darwin-informed theory of evolutionary change, the underpinning of his theory of capitalism as well as his treatment of engineers. In conclusion we shall argue that a number of interpretations of *The Engineer*s *and the Price System* have been too narrowly focused on actual occur-

S. H. Christensen (✉)
Department of Development & Planning, Aalborg University, Aalborg, Denmark
e-mail: steenhc@plan.aau.dk

B. Delahousse
Département Mesures Physiques, Université de Lille – IUT « A » de Lille,
Villeneuve d'Ascq Cedex, France

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_7

rences in engineering in order to subject Veblen's claim to a reality test but thereby neglecting the theoretical system behind the claim, with the result that a more balanced assessment of the critical potential of Veblen's theoretical system, and his key insights regarding the inherent contradictions of capitalism have been lacking.

Keywords Industry-business dichotomy · Imbecile institutions · Machine discipline · Socialistic disaffection · Soviet of technicians · Absentee ownership

7.1 Introduction

Thorstein Veblen's view regarding engineers and their possible role as a new class of corporate employees with the potential to delegitimize the prevailing business ideology for a final socialist overturn is closely related to his theory of capitalism. The evolution of his thought regarding American capitalism extended over more than 40 years from his first article in economics, *Mill's Theory of the Taxation of Land* published in 1882 (Camic and Hodgson 2011), to his last book *Absentee Ownership: Business Enterprise in Recent Times: The Case of America* published in 1923. Veblen's substantive interest was to understand the origin, nature, and future of industrial capitalism (Edgell 2001). His theorizing was based on what he observed over the half-century from 1875 to 1925, a period in which the United States shifted from farm to factory and from rural and regional economies to national and international business (Hake 2007). Reflecting the advent of corporate capitalism Veblen treated the United States as an ideal type of an advanced capitalist society as earlier Marx had assigned that role to Great Britain (Sweezy 1958).

Veblen's early writings on "technicians" started with the only published response he ever made to a reviewer (Dorfman 1934), namely *Mr. Cumming's Strictures on "The Theory of the Leisure Class"* published in 1899, followed by the article *Industrial and Pecuniary Employments* published in 1900, and his second book *The Theory of Business Enterprise* from 1904. His mid-career and later writings on "technicians" and engineers comprised his 1914 book *The Instinct of Workmanship and the State of the Industrial Arts* and his three post-World War I books *The Vested Interests and the Common Man* from 1919, and its 1921 follower *The Engineers and the Price System,* and finally *Absentee Ownership: Business Enterprise in Recent Times: The Case of America* from 1923. With its focus on engineers both in title and substance *The Engineers and the Price System* stands apart from the more dispersed treatment of "technicians" and engineers in the 1914 book and the other two post-World War I books.

The Engineers and the Price System has in particular attracted commentary from macro-economic sociologists, institutional economists, and Veblen scholars on the one hand who have been concerned with engineers either separately or as part of Veblen's research program on social movements (e.g. Bell 1963; Stabile 1986, 1987, 1988; Rutherford 1992; Knoedler and Mayhew 1994; 1999; Knoedler 1997) and from historiographers of engineering on the other hand who have been concerned not so much with Veblen's work as with engineering ideologies competing for supremacy during the process of professionalization of American engineers (e.

g. Layton 1962, 1971; Noble 1977; Meiksins 1988; Kline 2008; Kranakis 2010). The correspondence between the two groups is that for both of them the interpretation of the so-called "Revolt of Engineers" originally labelled by Edwin T. Layton Jr. has been a case in point.

Our approach to *The Engineers and the Price System* in this chapter is related to Veblen's macro-economic sociology. According to Stephen Edgell (1975) two related levels of theorizing can be distinguished in Veblen's macro-economic sociology: (1) a general evolutionary theory including his theory of capitalism, and (2) specific theories of selected phenomena to which Veblen's research program on social movements belongs. Frequently the latter is examined without reference to the former, which is unfortunate as it is Veblen's general theory that informs his special theories and not the other way around. Veblen's research program on social movements should therefore be seen in the light of his Darwin-informed evolutionary theory. By way of illustration Veblen in *The Engineers and the Price System* asserts that the sociological significance of the fundamental change that took place in the transition from the eighteenth to the twentieth century is the following:

> Revolutions in the eighteenth century were military and political; and the Elder Statesmen who now believe themselves to be making history still believe that revolutions can be made and unmade by the same ways and means in the twentieth century. But any substantial or effectual overturn in the twentieth century will necessarily be an industrial overturn; and by the same token, any twentieth century revolution can be combatted or neutralized only by industrial ways and means. (Veblen 1921, p. 104)

Referring to the above quotation Daniel Bell notes that *The Engineers and the Price System* is "squarely at the center of the preoccupation that attended the rise of sociology since its beginnings in the nineteenth century: namely, the scanning of the historical skies for portents of "the new class" which will overturn the existing social order" (Bell 1963, p. 616).

The point of departure for our interpretation of Veblen's (1921) book *The Engineers and the Price System,* originally published as a series of essays in *The Dial* from April to November 1919 (Dorfman 1934), is the debate that has built up over the years related to his projected "Soviet of Technicians". Malcolm Rutherford (1992) has summarized the debate into two main issues: (1) the compatibility between Veblen's focus on engineers with his previously articulated analyses of institutional change and social movements, and (2) Veblen's ideal political economy and the role engineers are supposed to play within that ideal. With respect to the former Edwin Layton has argued in favor of a non-compatibility position, claiming that "the evolution of Veblen's thought concerning engineers owed less to theory than to actual occurrences" (Layton 1962, p. 66). A non-compatibility position has also been promoted by Rick Tilman who has argued that Veblen's work on the engineers only represents a small and atypical part of his work (Tilman 1972), a position which has been characterized by Donald Stabile as being that *The Engineers and the Price System* "should be interpreted as an aberration, with Veblen's views on engineers excluded from the main corpus of his work" (Stabile 1988, p. 211).

Regarding the second main issue, Veblen's ideal political economy, Daniel Bell asserts that Veblen's view was that of a technocratic elitism (Bell 1963). H.J. Hodder finds a "constant theme of philosophical anarchism" in Veblen's work (Hodder

1956, p. 356) whereas Tilman finds a strong element of "anarcho-syndicalism" (Tilman 1972, p. 315), and additionally argues that in Veblen's policy prescription there is "a strong vein of what might be called "utopian realism."" (Tilman 1973, p. 161). A slightly different view is that of Louis Patsouras who argues that Veblen "took it for granted that the new institutions, those of a syndicalist state, would be of a non-coercive nature" (Patsouras 2004, p. 110).

Besides the two issues of the debate as summarized by Rutherford there is an additional issue, namely the question whether Veblen busied himself with making predictions, even "strange predictions" as suggested by Layton (1962). Such view would seem problematic considering Stephen Edgell's argument that

> (all) instinctive behavior is subject to development and hence modification by habit….when this element of Veblen's social theory is combined with his Darwin-informed opposition to teleology, it is difficult to construe that he was concerned to predict the future, since he argued that the outcome of the "process of cumulative change" was "something of a blind guess." (Edgell 2001, p. 142)

In the following we will argue that some of the interpretations of Veblen's treatment of engineers as represented by some of the issues and claims above are unconvincing and should be revised in the light of four interpretive key recognitions, namely that:

1. Veblen is consistent in his treatment of engineers from his early writings on "technicians" in *Mr. Cumming's Strictures on "The Theory of the Leisure Class"* (Veblen 1899a, b), *Industrial and Pecuniary Employments* (1900) and *The Theory of Business Enterprise* (1904) to his mid-career and later treatment of engineers in *The Instinct of Workmanship and the State of the Industrial Arts* (1914), *The Vested Interests and the Common Man* (1919), *The Engineers and the Price System* (1921), and *Absentee Ownership; Business Enterprise in Recent Times* (1923).
2. During The Progressive Era 1890–1920 many engineers presented arguments similar to those that Veblen used in his own discussions of the American business system and the possible role of engineers in delegitimizing and overthrowing it. This course of events is usually referred to as "The Revolt of Engineers". Veblen knew quite well that the movement of progressive engineers was waning.
3. As Veblen's Darwin-informed opposition to teleology would make predictions meaningless his *Soviet of Technicians* should be seen as an expository device for surveying the dichotomy between industry and business in the context of the 1917 Bolshevik Revolution in Russia, the ensuing American 1918–1921 Red Scare campaign, and the turbulent post-WW1 period which caused production needs to decline and unemployment to rise thereby highlighting the waste, conflicts, and frustrations of modern industrial capitalism.
4. Although one can find discussions of Veblen's ideal political economy throughout his works, Veblen articulated his definitive statement of the good life in *The Engineers and The Price System*. Veblen's vision of the good life was a cooperative, non-wasteful industrial democracy aimed at maximizing the economic welfare of the common man. His policy prescription is premised on anarcho-

syndicalist traditions and his view regarding the transition to the syndicalist state through a general strike should be seen as an expression of utopian realism.

In establishing these four interpretive key recognitions we have drawn on the work of Hill (1958), Tilman (1988), Knoedler and Mayhew (1999), Edgell (2001), Spindler (2002), and Knoedler (2007).

In the following section we will give a brief and highly selective account of Veblen's industry-business dichotomy and his theory of capitalism, the theoretical backdrop for his early as well as his later treatment of engineers. In Sect. 7.3 we will analyze *The Engineers and the Price System* in the light of the four interpretive key recognitions given above. This is followed by Sect. 7.4 in which we will briefly review Veblen's Darwin-informed theory of evolutionary change which is underpinning his theory of capitalism as well as his treatment of engineers. Finally in the last Sect. 7.5 we will conclude on our Edgell-informed approach to the interpretation of *The Engineer*s *and the Price System*.

7.2 The Veblenian Industry-Business Dichotomy

To briefly examine Veblen's hypothesis regarding a growing antagonism between industry and business it will be useful to consider: (1) Veblen's analysis of capitalism, and (2) the sociological implications of his analysis.

1. The main focus of attention in Veblen's social theory was to theorize and assess what he saw as a fundamental reorganization of capitalism and its cultural orientations in the transition from the eighteenth to the twentieth century. According to John Latsis (2010) the importance of Veblen's theoretical contribution is that he: (1) disclosed the predatory underpinning of property ownership (Veblen 1899a, b), (2) denounced the "pecuniary emulation" associated with consumption (Veblen 1899a, b), (3) dismissed the economic importance of loan credit and financial instruments (Veblen 1904), and (4) charged business management with "conscientious withdrawal of efficiency" (Veblen 1921).

Veblen's dichotomizing of business and industry implies that business is exclusively concerned with pecuniary values on the one hand and that industry is exclusively concerned with material production on the other. The relationship between the two is that business animates industrial activity under the guiding concerns of profit. In Veblen's theory of capitalism both absentee owners and captains of industry operate in the sphere of business usually at cross purposes with industry (Sweezy 1958). Moreover Veblen regarded technological knowledge related to material production as a joint possession of the community, and its advance as a social process. The technological application of this knowledge – "The state of the industrial arts" – determines the productive capacity of any given community. Veblen argued that the ownership and usufruct of this joint stock of technological knowledge had been monopolized by a small segment of the community – the vested interests – consisting of people lacking in technological ability and therefore unable to contribute creatively to its further advance (Veblen 1919).

As pointed out by Michael W. Hugley and Arthur J. Vidich (1993), during the latter part of the nineteenth century it became possible through improvements in machine technology to produce nearly unlimited quantities of almost any commodity. Through this achievement productive capacity had reached a point where the economy was no longer one of scarcity but instead one of abundance. Thereby the organizing principles of capitalism and its logics of production and modes of distribution were changed. Veblen thus observed that the original movers of industry such as industrialists**,** engineers, and other groups engaged in the productive work of the older capitalism had been replaced by businessmen, accountants, bankers and managers of money. As a result the new business spirit was dedicated to speculations in value and restriction of productive efficiency and output for the purpose of controlling prices. Veblen first noticed the emergence of this change of cultural orientations among robber barons and "captains of industry" (ibid., passim, pp. 492–495).

The new industrial order meant that the locus of business competition shifted from productive efficiency to competitive distribution of goods. Competitive distribution of goods required that vast resources were devoted to salesmanship and advertising (ibid, p. 495).

Associated with Veblen's industry-business dichotomy is another Veblenian dichotomy, namely that between technology and institutions. Veblen generally held that technology was good, socially useful and moral, whereas institutions were seen mainly as bad, inefficient and immoral (Latsis 2010). In dealing with obvious examples of what Veblen saw as bad institutions such as for example the leisure class, nationalism and absentee ownership he often used the epithet "imbecile" to characterize them. This view is underpinning Veblen's analysis of capitalism in his 1919 book *The Vested Interest and the Common Man*. His central thesis here is that the profound crisis of the twentieth century is the outcome of a tension between a social order that was stabilized in the eighteenth century and the new industrial order which developed within eighteenth century institutions of unrestricted private property, the sovereign nation state, and parliamentary democracy. The constituent principles of the stabilized social order were those of equal opportunity, self-help, free bargaining, and contract originally derived from the technological conditions of the earlier handicraft phases of industry. In *Absentee Ownership* Veblen characterized the tension this way:

> The driving forces of change have taken direct effect in the industrial arts, and have touched matters of law and custom only at the second remove. Habits of thought have therefore not been displaced and shifted forward to a new footing in law and morals in anything like the same measure in which men have learned to use new ways and means in industry. The principles (habits of thought) which govern knowledge and belief, law and morals, have accordingly lagged behind, as contrasted with the forward drive in industry and in the resulting workday conditions of living. (Veblen 1923, pp. 205–206)

Veblen argued that the new industrial order can function properly only if these stabilized institutional restrictions are abolished thereby ensuring maximum production for the benefit of the common man.

2. The sociological implications of Veblen's theory of capitalism relate to his understanding of the rampant mechanization of the workplace that took place during his time. The key concepts in his understanding of this process, imbued with sociological implications, are those of "the machine process" and its psychological and cultural bearings through "the machine discipline". Veblen had noticed that machine tools and production lines were introduced at the turn of the twentieth century thereby radically changing the physical and psychological environment of the workplace, the organization of labor and the political landscape (Latsis 2010). It was a process of technological and organizational change from small-scale to large-scale production that took place during this period which intentionally or unintentionally served to collectivize the economic system. As the size of the firm took on a corporate form it was inextricably interwoven with the growth of collective action. It thus stimulated the development of large-scale social movements among workers and farmers (Gruchy 1958). In his research program on social movements the groups whose activities Veblen investigated included farmers, members of Coxey's army, devotees of the arts and crafts, the American Federation of Labor (AFL), and the International Workers of the World (IWW), and in particular three groups with the radical potential he was looking for, namely Bellamyites, workers, and engineers (Stabile 1988).

Moreover as pointed out by Rutherford (1998), the continued development of science and technology created an ever increasing specialization of occupations and "a widening gulf between the discipline of the pecuniary activity of the businessman and the discipline imposed on the worker and engineer in the mechanized industry" (Rutherford 1998, p. 471). Veblen grouped these specialized occupations into two major categories and conceptualized them in terms of what he called industrial and pecuniary employments. According to this conceptualization pecuniary or business employments are concerned with "exchange or market values and with purchase and sale…What holds the interest and guides and shifts the attention of men within these employments is the main chance. These activities begin and end within what may broadly be called "the higgling of the market"" (Veblen 1901, pp. 293–294). In contrast industrial employments are concerned with "the shaping and guiding of material things and processes…with material serviceability" (ibid., p. 294).

Veblen further argued that the scheme of knowledge brought in by machine technology is of "a skeptical, matter-of-fact complexion, materialistic, unmoral, unpatriotic, undevout" with a focus on "the law of cause and effect", and with the effect that "the machine discipline acts to disintegrate the institutional heritage, of all degrees of antiquity and authenticity" (Veblen 1904, p. 177). Furthermore "(the) machine technology is peculiarly designed to inculcate such iconoclastic habits of thought as come to a head in the socialistic bias… the machine technology not only trains the workmen into socialistic iconoclasm, it has also a selective effect" (Veblen 1904, pp. 166–167).

Regarding Veblen's view on the "selective effect" of machine technology it argues in favor of the consistency of Veblen's treatment of engineers and technicians in the sense that it implies that iconoclasm and availability for socialistic disaffection and propaganda among the industrial classes are graded on proximity to the machine process. In the farther remove of the machine process unskilled workers and supporters of conventional notions of property and ownership such as farmers and professional groups comprising lawyers, bankers and brokers etc. are to be found. Accordingly Veblen's view puts to the forefront among the industrial classes given to socialistic iconoclasm "the higher ranks of skilled mechanics, and perhaps still more decisively… those who stand in an engineering or supervisory relation to the processes" (Veblen 1904, p. 149). This view promoted in 1904 fully corresponds to the view Veblen promoted in 1921 in *The Engineers and the Price System.*

In closing this section a brief commentary with respect to the validity of Veblen's central hypothesis regarding "the discipline of the machine process" should be in place. According to Veblen:

> Wherever and insofar as the increase and diffusion of knowledge has made the machine process and the mechanical technology the tone-giving factor in men's scheme of thought, there modern socialistic iconoclasm follows by consequence. (Veblen 1904, p. 168)

> The discipline of the machine process cuts away the spiritual, institutional foundations of business enterprise; the machine industry is incompatible with its continued growth… In their struggle against the cultural effects of the machine process, therefore, business principles cannot win in the long run. (Veblen 1904, p. 177)

The brief quotations above convey the essence of Thorstein Veblen's hypothesis regarding the psychological and cultural effects of the machine discipline. Veblen's theorizing regarding engineers and technicians and their possible role as revolutionary actors hinges on the validity of that hypothesis. Therefore juxtaposing Veblen's hypothesis with "actual occurrences" or more precisely with the historical reality would be the best way to test his hypothesis and to provide rich and more detailed explanations for its apparent failure both with respect to the revolutionary potential of engineers and the withering of business principles.

However this is not our intention at this place. Instead we wish to conclude more positively on how Veblen deconstructs the engineering-business nexus by saying that the enduring value of Veblen's theorizing of the machine discipline is that he has shown how changes in the "technology of the workplace shape and condition perceptions, habits and practices that go well beyond it" (Latsis 2010, p. 606). In this way Veblen has made an important contribution to the emerging discipline of his day, namely industrial sociology (Banks 1959). Additionally Veblen provides "a descriptively rich account of how interaction with new tools transforms the perceptions of workers bringing new contradictions to light and stimulating new habits" (Latsis, p. 606). On the business side Veblen's main point is still relevant, namely that the central goal of modern industrial capitalism is to create income streams from three different sources: (1) productive activity, (2) financial capitalization of assets, (3) disruption of productive activity, with a view to maximizing the return on invested capital, both tangible and intangible. Business leaders and absentee owners are more often than not indifferent about how this is best accomplished (Cornehls 2004).

7.3 Analysis of *The Engineers and the Price System*

The Engineers and the Price System is organized in six chapters which, as we have noted earlier, were originally published as a series of essays of their own. While the first three chapters are devoted to the analysis of the problems inherent to capitalism – the price system, the industrial system, the captains of finance and absentee owners – which Veblen developed recurrently in his earlier works, the next three chapters obviously focus on the central thesis of this book: the engineers' present status and their potential role in revolutionizing modern society. In this section, we will analyze the different themes developed in *The Engineers and the Price System* in the light of the four interpretive key recognitions which we defined earlier in the introduction: (1) Veblen's consistency in his treatment of engineers, (2) his awareness that the potential revolutionary force of the engineers was waning during the first quarter of the twentieth century, (3) his projected Soviet of Technicians which is to be seen as an expository device for highlighting the dichotomy between industry and business, (4) his vision of the good life based on the material welfare of the community.

In *The Engineers and the Price System* Veblen typically begins by stating a problem, namely "the inescapable opposition of interests between the needs of business and the needs of the community" (Spindler 2002, p.70) in a capitalistic society, which is followed by a provocative solution: a revolutionary overturn led by technicians and engineers which would culminate in a "Soviet of Technicians". His theory is that the price system, modern capitalism, cannot be maintained for long in any country without what he calls a "conscientious withdrawal of efficiency", including different forms of "sabotage", which serves business to secure the largest obtainable net profit by controlling the industrial production, insofar as

> the rate and volume of output must be adjusted to the needs of the market, not to the working capacity of the available resources, equipment and man power, nor to the community's needs of consumable goods. (Veblen 1921, pp. 43)

Veblen points out that the early years of the twentieth century have been marked by an "efficient enlargement of industrial capacity [which] has been due to a continued advance in technology, to a continued increase of the available natural resources, and to a continued increase of population" (Veblen 1921, p. 58). These advances, together with the lesser competition between major industries, have entailed an increased productivity which should contribute to the community's material welfare in terms of an easier access to employment and to the consumption of indispensable goods and services. But, according to Veblen, the business men have always been in a position to hold this productive capacity in check for their own interests and those of the absentee owners whom they represent. Thus for Veblen the main issue is that the unemployment of resources, equipment and man power is not the result of the dysfunction of the business system but is intrinsic to it since full production is contrary to the pecuniary interests of absentee owners.

The continued progress in the productive capacity of the industrial system has had another effect: the increased financial role of the entrepreneur, the captain of industry, who originally was "a cross between a business man and an industrial expert" (ibid, p. 59). Due to the large scale and specialization of modern industry, the captain of industry has been more and more involved in the financial side of management to the detriment of the technological side, thus turning into a corporate financier and, later, a captain of finance. As a result,

> the business men are increasingly out of touch with that manner of thinking and those elements of knowledge that go to make up the logic and the relevant facts of the mechanical technology. (ibid, 1921, p. 63)

For Veblen, the captains of finance may be experts in prices and profits and continue to control the industrial production but they have lost touch with the management of industrial processes; this situation has resulted in increased waste and misdirection. And "it is the industrial experts, not the business men, who have finally begun to criticize this businesslike management and neglect of the ways and means of industry" (ibid, p. 66). Veblen then highlights two factors of progressive change: (1) engineers, industrial experts and technicians have gradually been taking up responsible positions in industry and their numbers have increased, so that they constitute one "pillar" of the corporate enterprise, (2) the large financial interests, the second "pillar", have progressively acknowledged that corporation finance should be managed as an administrative routine.

The analysis of the American industrial system at the turn of the twentieth century is another important issue in that it contributes to outline the framework of the engineer's status and role according to Veblen. He describes this system as being: *mechanical* insofar as primacy is given to the organization of mechanical powers and material resources, not to the management of human resources, *comprehensive* as it includes productive forces as well as commercial ones even though they are mostly antagonistic, *inclusive* as it runs on diverse "interlocking mechanical processes, interdependent and balanced among themselves", and *of an impersonal nature* since by making use of material sciences it aims at "quantity production of standardized goods and services" (Veblen 1921, p. 72). Such a complex system requires systematic control on the part of industrial experts, or "production engineers"; they constitute the General Staff of industry "whose work is to control the strategy of production at large and to keep an oversight of the tactics of production in detail" (ibid, p. 73). Veblen sees these experts and engineers as indispensable to the functioning of the industrial system of the new order since they have all the competences, knowledge and experience required to manage it.

> The material welfare of the community is unreservedly bound up with the due working of this industrial system, and therefore with its unreserved control by the engineers, who alone are competent to manage it. To do their work as it should be done, these men of the industrial general staff must have a free hand, unhampered by commercial considerations and reservations. (Veblen 1921, p. 83)

Thus by emphasizing the fundamental necessity of the engineers' independence from business and their responsibility toward the community, Veblen re-asserts his criticism of the system as it actually stands: in spite of a number of advances the power still remains in the hands of the absentee owners who continue to control the system in their own interests and limit the engineers' discretion since they are mere employees of the captains of industry. As we have shown in the previous section and as outlined by Stephen Edgell, this particular status of the engineer has been consistently treated in Veblen's earlier and later works:

> Since the late 1890s Veblen had been concerned with the economic and political significance of technical experts, whom he regarded as the contemporary embodiment of the instinct of workmanship and therefore as a potential solution to the problem of the regular sabotage of industry perpetrated by the business class in their routine preoccupation with the "pecuniary side" of economic processes. (Edgell 2001, p. 137)

Edgell's view on the continuity of Veblen's appreciation of the role of engineers is supported by Knoedler and Mayhew who point out that Veblen's analysis in *The Engineers and the Price System* is the same as his discussions of "Industrial and Pecuniary Employments" in the early 1900s, and that "[f]rom the 1880s through the 1920s many engineers presented arguments that closely paralleled those that Veblen used" (Knoedler and Mayhew 1999, pp. 255–256).

Even though Veblen notes that until the end of the nineteenth century the technologists had not been able to form any credible movement of protest against this system, he acknowledges that at the dawn of the twentieth century they have begun to develop a "class consciousness" by realizing that they were together the indispensable General Staff of the industrial system (Veblen 1921, p. 84). They have also become aware of the mismanagement of industry, and the resulting waste and confusion, due to the ignorance of the representatives of absentee owners and their commercial sabotage. Knoedler and Mayhew observe that the engineers' discontent with business methods reflected the views of a progressive minority and that although "it seems likely that Veblen read and was influenced by them" (Knoedler and Mayhew 1999, p. 262), he does not seriously consider them "as potential revolutionaries because of their position in the traditional distributionally-defined class system (ibid, p. 263). Besides he is quite percipient of the self-interest of a growing number of engineers as they take up responsible positions in the management of industry. However Veblen also points out to the attitude of the younger generation of engineers who have another view of engineering, away from its commercial tradition, as they

> are beginning to understand that engineering begins and ends in the domain of tangible performance, and that commercial expediency is another matter… commercial expediency has nothing better to contribute to the engineer's work than so much lag, leak, and friction. (Veblen 1921, pp. 85–86)

As a result of this class consciousness and economic awareness, Veblen posits that the engineers, and the technologists at large, are the only professional class "in a position to make the next move" (ibid, p. 89), i.e. the revolutionary overturn. To that effect, he dismisses the negotiations between the owners and workers' organizations, capital and labor, as being inevitably inconclusive since they are mere business transactions in which each party acts as a vested interest, so as to get a profitable bargain for itself and its members. On the contrary, the engineers and technicians are a small but homogeneous group of well-trained and competent specialists, who are not driven by a commercial interest and are indispensable to the conduct of industry. Thus, they constitute a sufficient force to organize a revolutionary overturn, all the more so as

> they are the leaders of the industrial personnel, the workmen, of the officers of the line and the rank and file; and these are coming into a frame of mind to follow their leaders in any adventure that holds a promise of advancing the common good. (ibid, p. 89)

Following on from his analysis of the problems inherent to modern capitalism, Veblen devotes the second part of *The Engineers and the Price System*, actually the last three chapters of the book, to what he posits as practicable solutions to these problems. The first prerequisite Veblen insists on throughout these three chapters is that, to get the necessary popular support from the workmen and the rank and file as well as to expect even a temporary success of the movement, it is essential for technicians-engineers to rely on an organization which has devised a plan of action and can efficiently take over the country's productive industry from the start, so as to guarantee the material welfare of the population "whose livelihood depends on the effectual working of its industrial system from day to day" (ibid., p. 99). The existing organizations like the American Federation of Labor and the Industrial Workers of the World not only lack this industrial expertise but they are also over-concerned with the "full dinner pail", as Veblen puts it. As a result, their modes of action are limited to sabotage which Veblen regards as "an everyday expedient of business" (p. 99). These organizations therefore do not constitute a menace to the Vested Interests, nor does the example of the then recent Soviet Russia have much direct impact on the American society since "the situation in America does not now offer such a combination of circumstances as would be required for any effectual overturn of the established order" (ibid. p. 96). Veblen then concludes that the nature of revolutions has changed from "military and political" in the eighteenth century to "industrial" in the twentieth century, which requires a new organization based on technologists:

> These main lines of revolutionary strategy are lines of technical organization and industrial management; essentially lines of industrial engineering; such as will fit the organization to take care of the highly technical industrial system that constitutes the indispensable material foundation of any modern civilized community. (Veblen 1921, pp. 103–104)

At the same time, Veblen pretends to reassure the guardians of the Vested Interests by noting that they are secure, *just yet* (a recurrent ironical phrase of his), "so long as no practicable plan has been provided for taking over the management from the dead hand of the Vested Interests" (ibid., p. 105), thus almost certainly reinforcing their apprehension.

Another issue addressed by Veblen bears upon the circumstances which may lead to a radical change, namely the increasing wastefulness and inefficiency of industrial production. He distinguishes four main lines of waste and obstruction in the businesslike management of production: (1) unemployment of material resources, equipment and man power, (2) salesmanship, and particularly advertising, (3) production and sales cost of superfluities, (4) systematic dislocation, sabotage and duplication (ibid, p. 112). These four ordinary practices of business enterprise inevitably result in the continual increase of sales costs to the profit of the business people and at the same time to the detriment of the underlying population since it uses up their productive forces and increases the cost of living. For Veblen, this state of things will "reasonably" end up 1 day in the workmen becoming aware of their plight and losing trust in the system, thus creating the conditions for a revolutionary overturn. But immediately after he notes that it is as well reasonable to think that such a collapse is not for the near future and has little chance to be perpetrated by the underlying population as they are used to putting up with their hardship and "are not in the habit of thinking about these things at all" (ibid, p. 117). Veblen does not believe either that the collapse of the Vested Interests will be brought about by their self-made abdication, "not so long as there is no competent organization ready to take their place and administer the country's industry on a more reasonable plan" (ibid, p. 121). Modern industry has to be highly productive by making use of technological advances and a wide and varied range of materials from different sources. But as the captains of industry who represent the absentee owners are ignorant in these matters,

> [it] follows that those gifted, trained, and experienced technicians who now are in possession of the requisite technological information and experience are the first and instantly indispensable factor in the everyday work of carrying on the country's productive industry. They now constitute the General Staff of the industrial system, in fact. (ibid, p. 127)

Thus Veblen assigns technicians and industrial experts a key role in setting up a new order in the form of a "Soviet of Technicians", but he repeatedly makes it clear that this is a "remote contingency in America" because the members of the General Staff are not yet ready for such a venture: not only they are "a harmless and docile sort, well fed on the whole and somewhat placidly content with the full dinner-pail" (ibid, p. 128) but also, apart from the younger generation, they have always accepted their status of mere employees of financiers, with no word to say in the conduct of the system. Yet Veblen insists that technicians have a heavy responsibility to assume towards the community at large, since they have benefited during their training from the joint stock of technological knowledge passed on to them by that community. Hence, strategically, not only they have the competence to impose their leadership, provided they act collectively and have devised a concerted plan of action, but it is also their duty to reciprocate to the community by contributing to the material welfare of its people.

In the last chapter of *The Engineers and the Price System* Veblen summarizes in a memorandum the main lines of the plan of action he regards indispensable to implement a Soviet of Technicians: its objectives, its organizational structure, the preparations that would need to be made, its ways and means. This soviet would constitute itself as an industrial directorate whose duties should focus on: (1) the due allocation of resources and reasonable employment of the available power, equipment and man power, which ranks as a priority for Veblen, (2) the avoidance of waste and duplication of work, (3) the equitable supply of goods and services to consumers. The contemplated directorate would have a tripartite composition: production engineers who alone are competent to initiate this enterprise, representatives of the transportation and distribution systems whose support is indispensable, and consulting economists who are "a necessary adjunct to the directorate personnel" inasmuch as they have, by training, a proper insight into economic forces. Veblen imperatively excludes from this directorate "all persons who have been trained for business or who have had experience in business undertakings" (ibid, p. 137) as they are irretrievably biased in their businesslike ways of thinking, thus pursuing the safeguarding of investments and commercial profits.

In his memorandum Veblen also stresses the fact that a plan of action for the overturn of the established order cannot be undertaken without serious preparations comprising two main lines: a survey of existing conditions and of the available ways and means, and the setting up of practicable organization tables together with a study of the available personnel. The survey will focus on, and highlight, the different kinds of waste of the businesslike control of industry, the causes of these practices, and the practicable economies of management and production that can be applied. As regards the organization tables, they are meant, in Veblen's view, to provide for an equitable and efficient distribution of goods and services to consumers by re-organizing the present wasteful traffic. To make these two lines of preparation effective, Veblen calls for "diligent teamwork" involving both engineers and economists with a common interest in productive economy. Besides drawing these experts together to devise the new order, the survey will also be useful in pedagogical terms in that it will display to the whole community the inherent defects of the existing order, the reasons for these defects and the expected benefits of an industrial management without absentee ownership.

As for the revolutionary overturn itself, Veblen makes it clear that "the move will be of the simplest and most matter-of-fact character" (ibid, p. 143) and need involve no violence nor mass demonstrations.

> In principle, all that is necessarily involved is a disallowance of absentee ownership; that is to say, the disestablishment of an institution which has, in the course of time and change, proved to be noxious to the common good. (ibid, p. 143)

This act of disallowance of absentee ownership will have no major impact on its own on the ways and means of industry except for those that Veblen calls the "kept classes" who benefit from the old order and have no experience of hardship. It will then be the role and duty of technicians, within the contemplated soviet, to take over the economic affairs, since they are the ones who have a good insight into the country's available resources, who put in practice the joint stock of technical knowledge and who take care of the community's need and use of consumable goods (ibid, p. 101). Veblen finally comes to the conclusion that the "revolutionary" move that is actually required is a general strike, with sufficient support from the country's technicians and industrial rank and file to incapacitate the industrial system and do away with the established order imposed by absentee owners.

Veblen immediately tones down his conclusion with the enumeration of obstacles that will hamper the achievement of the general strike he has just advocated: the engineers are contented subalterns of the absentee owners, the working force have no sympathy for technicians, and the underlying population are hardly informed of the state of things. This additional statement, together with the ironical remarks reiterated throughout the book that absentee ownership is secure "just yet" and that an overturn is a remote contingency, substantiates the argument that Veblen does not make a prediction on the feasibility of a revolution in America but, as Rick Tilman puts it, that his proposal of a Soviet of Technicians is to be seen as "an expository device expressing satirical intent, not as a serious plan for economic reconstruction" (Tilman 1988, p. 1248). The authors of this chapter share this view and additionally argue that this rhetorical device enables Veblen to formulate his analysis of the dichotomy between business and industry, as can be observed in the last chapter of his book in which he keeps contrasting them on a number of relevant issues.

If *The Engineers and the Price System* does not lay down a credible plan for an economic change, it does offer an articulated vision of the good life which Veblen discussed throughout his works. As pointed out by Janet Knoedler, the book "sets forth his most detailed statement of the good life" in a good society.

> It was a good life lived in a good society, that is, a society that was industrial, in Veblen's sense of the word, cooperative, non-wasteful, prosperous and democratic, organized as a modern and intelligent democracy governed collectively by modern values of rationality, industry and efficiency, to provision all of its members. (Knoedler 2007, p. 203)

For Veblen this good life is based on full industrial production and technical efficiency, reduction of unemployment and scarcity and due allocation of resources and distribution. To attain this goal Veblen argues that the engineers are the most likely agents of the social overturn that will bring about the material welfare of the common man since they alone can correct the shortcomings of the established order and create a new economic order.

As noted by Tilman (1972, 1973), Veblen in his policy prescription is in line with anarcho-syndicalist traditions with a strong element of what he calls "utopian realism". The authors of this chapter share this view. The "utopian" aspect relates to the fact that Veblen claimed that the transition to the syndicalist state could occur peacefully and that Veblen ignored the possibility of a counter-revolution on the part of the vested interests, of which history gives so many examples. The aspect of "realism" relates to the fact that the policy prescription Veblen outlined is guided by a thorough theoretical analysis of corporate capitalism.

7.4 Veblen's Darwin-Informed Theory of Evolutionary Change

> Modern science demands a genetic account of the phenomena with which it deals, and a genetic inquiry…will have to make up its account with the earlier phases of cultural growth. (Veblen 1908, pp. 39–40)

> A genetic inquiry into institutions will address itself to the growth of habits and conventions, as conditioned by the material environment and by the innate and persistent propensities of human nature, and for these propensities, as they take effect in the give and take of

> cultural growth, no better designation than the time worn "instinct" is available. (Veblen 1914, pp. 2–3)

The purpose of this section is to locate Veblen's main concerns in *The Engineers and the Price System* – the conflict between productive capacity (industry) and institutional restriction (business) – within his Darwin-informed theory of evolutionary change. The section therefore briefly considers the component parts of his evolutionary theory: the state of the industrial arts, instincts, habits, institutions, and evolutionary stages.

As illustrated by the two quotations above Veblen was a cultural geneticist whose overall theoretical contribution was focused on the nature, origin, evolution, and effects of institutions. According to Stephen Edgell and Rick Tilman (Edgell and Tilman 1989) Veblen's theory of evolutionary change is indebted to "two basic facts and the inescapable conclusion" that followed from them in Charles Darwin's theory of evolution as presented in his 1859 book *The Origin of Species by Means of Natural Selection*, *or the Preservation of favored Races in the Struggle for Life.* Darwin's deduction runs this way: (1) species vary enormously, (2) species tend to reproduce on a scale that precludes the survival of all but the fittest, and the conclusion, (3) in the ensuing struggle for existence, the variations that are best adapted to their environment will survive (Edgell and Tilman 1989, p. 1005). Accordingly evolution has no direction, no purpose and no ameliorative effects. Evolution is a process of blind drift.

Veblen outlined the methodological principles behind his theory of evolutionary change in three seminal essays published in the decade between 1898 and 1908. The three essays are: *Why is Economics not an Evolutionary Science* (1898a), *The Place of Science in Modern Civilization* (Veblen 1906a, b), and *The Evolution of the Scientific Point of View* (1908). These essays were later included in the Veblen collection *The Place of Science in Modern Civilization* (1919). In the three essays Veblen defined a post-Darwinian program for all sciences. Based on these three essays and three more from the same collection, namely *The Preconceptions of Economic Science I* (1899), *II* (1899), *III* (1900), in Table 7.1 below we have composed a taxonomy of methodological principles used positively by Veblen in his own evolutionary theory and negatively in his critique of contemporary and classic economists and social scientists.

Veblen's indebtedness to the Darwinian deduction presented at the beginning of this section is most clearly stated in a passage in *The Theory of the Leisure Class.* Here Veblen stated that "the evolution of social structure has been a process of natural selection of institutions" (Veblen 1899a, b, p. 125). Following Darwin, Veblen substituted the notion of "institution" for Darwin's reference to "species". This view, that "institution" is the unit of selection, is a key point elaborated in Geoffrey M. Hodgson's interpretation of Veblen (Hodgson 1992, 2004). Hodgson additionally argues that Darwinism is only used by Veblen as a metaphor (Hodgson 1992), a position which at first sight seems counterintuitive but which we support.

Table 7.1 A taxonomy of Veblen's methodological principles

Positive	Negative
Scientific	Animistic[a]
Matter-of-fact	Make believe
Dynamic	Static
Genetic	Ahistorical
Inductive historically grounded analysis	Deductive logic
Post-Darwinian	Pre-Darwinian
Equilibrium rare	Equilibrium normal
Habituation of thought and action	Hedonistic calculus of pleasure and pain
Ceteris paribus assumptions useless	Ceteris paribus assumptions necessary
Undirected process of blind drift	Ameliorative – progressive process
Impersonal causal sequence	Preordained ends
Cumulative causation	Universal laws
Materialism	Spiritualistic – providential
Non-teleological secular trend	Teleological order – final causes
Natural order	Divine necessity

[a]The animistic preconception means that phenomena are apprehended in terms of personality or individuality. It imputes to objects propensity, will-power, or purpose (see e.g. Veblen's 1899a [2007] article *The Preconceptions of Economic Science I,* pp. 102–103). One example used by Veblen is the teleology of Hegelian dialectics

Paradoxically however Hodgson's view has also implicitly been supported by Rutherford (1998) who with respect to the unit of selection disagrees with him. In his implicit support of Hodgson's view that Veblen's Darwinism is only a metaphor Rutherford has convincingly argued that there is a contradiction in Veblen, namely "that Veblen's system is not so much one of institutional variation followed by selection in the material environment as it was one of variation in the material environment itself promoting an adaptive institutional response" (ibid., p. 465). In support of Rutherford's interpretation we refer to the following quotation from The Preface to *The Instinct of Workmanship and the State of the Industrial arts*:

> It is assumed that in the growth of culture, as in its current maintenance, the facts of technological use and wont are fundamental and definitive, in the sense that they underlie and condition the scope and method of civilization in other than the technological aspect. (Quoted in Banks 1959, p. 233)

Veblen's theory of evolutionary change was therefore basically one in which new technology was seen as the driving force which changed the environment thereby leading to changing economic conditions which in turn resulted in new ways of thinking and thereby to the emergence of new institutions through a non-intentional process of habituation (Rutherford 1998).

As observed by Olivier Brette (2003) to be consistent with the results of other evolutionary sciences, most notably anthropology, psychology and biology, Veblen's theory of institutional evolution required that his representation of human nature would fit into these results. He therefore committed himself to the notion of instinct and defined human nature as “a coherent structure of propensities [instincts] and habits which seeks realization and expression in an unfolding activity” (Veblen 1919, p. 74). As indicated in the quotation Veblen often substituted various notions such as “proclivities, impulses, dispositions, spiritual endowments, propensities, and aptitudes” for the biological notion of instinct. Taken together these instinctive dispositions make up the “spiritual nature” of human beings (Veblen 1914, p. 14). As part of human biology instincts are hereditary traits (ibid, p. 13). Moreover as each instinct is of a teleological nature as opposed to institutions which are not, it is therefore guided by intelligence to a degree superior to that of other animals. However, as noted by Latsis (2010. p. 603) the teleological nature of instincts should not be confused with “the conscious beliefs and desires of individual agents”. Regarding the telos inherent in instincts Veblen argued that it is mediated “since a more or less extended logic of ways and means comes to intervene between the instinctively given end and its realization” (Veblen 1914, p. 6). Finally he emphasized that the way instincts operate is complex as instincts do not operate independently but are capable in countless ways to combine by blending, overlapping and interfering, sometimes jointly and sometimes in conflict (ibid, p. 9).

Veblen claimed that there are basically two clusters of instincts: group-regarding versus self-regarding instincts. The former cluster of instincts is characterized by their orientation toward serviceability or efficiency and a strong sense of the demerit of futility, waste and incapacity. The latter cluster is characterized by their orientation toward aggression in order to obtain goods and services by either seizure or compulsion (Edgell 2001). The fact that each cluster of instincts is guided by intelligence is the reason why there can be a conflict between them taking effect at different stages of evolution. Which cluster will take the upper hand at a given stage will, departing from the respective scheme of habituation and stabilized institutions of an older order, be determined by the pressure – “exigencies” – of the material and technological situation. For Veblen then, the key institutions are those based on the two instincts, workmanship and predation, which refer to the distinction between tools and weapons (Edgell and Tilman 1989). As the two instincts are omnipresent they can play out in countless ways in which either the one or the other takes the upper hand.

Veblen therefore made reference to four broad evolutionary stages: the savage era, the barbarian era, the handicraft era, and the machine era in which he examined the historical interaction of technology, instincts, habits and institutions (Edgell 2001). He divided the four eras into two main parts: (1) the peaceful prehistoric Savage State, and (i) the Predatory Culture, covering all subsequent historical time. Veblen subdivided the second part into cultural stages according to the type and degree of predatory patterns, namely: (2) the Barbarian State, which lasted through the Middle Ages and was characterized by military predation, and (ii) the Pecuniary Culture – characteristic of modern times and featured by pecuniary predation.

Veblen further subdivided Pecuniary Culture into two phases – (3) the Handicraft Era and (4) the Machine Age (Davis 1945, p. 146).

In Veblen's early works in the 1890s he distinguished between the group-regarding instinct of workmanship and self-regarding predation. In his 1898 article *The Instinct of Workmanship and the Irksomeness of Labor* Veblen characterized the difference between the two instincts in Darwinian terms saying "The former [workmanship] is a human trait necessary for the survival of the species; the latter [predation] is a habit of thought possible only in a species which has distanced all competitors, and then it prevails only by sufferance and within limits set by the former" (Veblen 1898b, p. 82). Veblen's occasional slippery use of concepts can be disconcerting, but the meaning of the quotation should be clear enough, namely that in order for the species to survive workmanship comes first, even though Veblen substitutes "human traits" and "habit of thought" for instincts.

In his later work published between 1900 and 1914 he added *idle curiosity* and the *parental bent* to the group-regarding instincts and *sportsmanship,* and *pugnacity* to the self-regarding instincts (Edgell 2001). The *parental bent* is to be understood as a predisposition concerned with the welfare of the young and the fortunes of the group. Of particular interest here is the instinct of *idle curiosity.* According to Veblen idle curiosity "counts up finally, because cumulatively, into the most substantial achievement of the race – its systematized knowledge and quasi-knowledge of things" (Veblen 1914, p. 87).

Overall *idle curiosity* may be seen as a dynamic element in social change as it refers to the human being's capacity "to think critically and coherently over wide areas of their experience" (Dugger 1995, p. 1017). *Idle* means, that no utilitarian aim enters in its habitual exercise. However, as argued by Rutherford the way idle curiosity works in Veblen's system is through technological change: "Idle curiosity is an instinctive drive to understand things and to construct systematized knowledge and it can create both "quasi-knowledge", in the form of myths and beliefs without any serviceable function, as well as knowledge that has serviceable technological application" (Rutherford 1998, p. 468).

As Veblen did not believe that social phenomena flow directly from a detailed account of human nature but held, as shown above, an adaptive view of social institutions his theory of evolutionary change put into prominence the concepts of habit and institution. His adaptive view of social institutions also meant that institutional inertia would create a time lag and a roadblock for change in order to prevent an old order from being destroyed. In his article *The Limitations of Marginal Utility* from 1909 included in *The Place of Science in Modern Civilization,* Veblen set forth the following view on institutions:

> They are principles of action which underlie the current, business-like scheme of economic life, and as such, as practical grounds of conduct, they are not to be called in question without questioning the existing law and order. As a matter of course, men order their lives by these principles and, practically entertain no question of their stability and finality. That is what is meant by calling them institutions; they are settled habits of thought common to the generality of men. (Veblen 1909, p. 239)

Veblen's definition "institutions-as-habits-of-thought" "common to the generality of men" given above in fact collapses thought and action into one another thereby perhaps indicating that Veblen's definition is too narrow (Latsis 2010). For lack of space we will not delve deeper into this issue as it has no bearings on our present argument.

In closing this section in which the component parts of Veblen's evolutionary theory – the state of the industrial arts, instincts, habits, institutions, and evolutionary stages – have been considered, three main conclusions can be drawn. The first is that cultural evolution throughout history is driven by the state of the industrial arts, or technological advances, which set off a chain reaction which eventually involves a conflict between the institutional forces that encourage transformation and those that enhance stability (Edgell 2001). The second conclusion relates to the specific nature of the institutional forces. The nature of these forces is conveyed in the words of Myron M. Watkins, namely that "the direction and pace of this process are set by the thrust of the self-regarding proclivities and the institutions embodying them and the counterthrust of the group-regarding proclivities and the institutions built upon their foundation" (Watkins 1958, pp. 254–255). The third conclusion is that the Machine Age is characterized by Pecuniary Predation. Hence from the perspective of Veblen's theory of evolutionary change his concerns in *The Engineers and the Price System* are located within the Pecuniary Culture. Despite differences in conceptual furniture and basic assumptions in Veblen and Marx – non-teleological Darwinian evolution versus teleological Hegelian dialectics – Veblen's view nevertheless brings to mind the dialectic between "the forces of production" and "the relations of productions" in the Marxian scheme (Sweezy 1958, p. 180).

7.5 Conclusion

The main objectives of this chapter were: (1) according to its title to examine Veblen's industry-business dichotomy and how it leads him already in his early writings to deconstruct the engineering-business nexus thereby construing engineers and technicians in the role as a potential class of revolutionary actors, and (2) to reinterpret *The Engineers and the Price System* from the perspective of Veblen's macro-economic sociology as presented by Stephen Edgell. The attempted reinterpretation was based on four key recognitions representing a synthesis of arguments which we have found convincing. Moreover our interpretation of *The Engineers and the Price System* has been based on two methodical premises which are reflected in the structure of the chapter: (1) it should be based on a close-reading of the text, and (2) it should locate the text both within the theoretical context of Veblen's theory of corporate capitalism as well as his Darwin-informed evolutionary theory.

Such modus operandi has allowed us to oscillate between Veblen's early and later work thereby showing the consistency of his view on engineers and technicians. It has not been the aim of the chapter to subject Veblen's central hypothesis regarding the psychological and cultural effects of the machine discipline, as presented at the end of Sect. 7.2, to a reality test. The authors of the chapter fully acknowledge that Veblen's central hypothesis did not stand a reality test. This has been abundantly clear from the works of many commentators of *The Engineers and the Price System* whose main concern it seems to have been. Engineers did not become revolutionary actors and business principles did not wither away. But as it has been shown this is not the whole story. The trial balance in our interpretation of *The Engineers and the Price System* is that on the one hand criticism of Veblen should be directed at his[1]:

- inconsistent use and labelling of "instincts";
- lack of detailed empirical evidence;
- construction of too simplistic and rigid dichotomies;
- Overestimation of the ability of the machine process to change the mindsets of industrial workers and thereby erode archaic habits of thought such as property rights and religion;
- Unwarranted belief in the revolutionary potential of engineers and technicians;
- arbitrary use of the notion of engineer, industrialist, and technologist

On the other hand Veblen's substantial and durable contribution is that he:

- Substantiated that economic activities are to be treated holistically as part of a complete social system;
- pointed to the business corporation as a key development in finance capitalism;
- was the first to point to the separation of ownership and control;
- enabled an understanding of why factories rarely worked at full capacity through his dichotomizing of business and production;
- identified the persistent presence of residual habits of primitive societies in modern American life.
- provided literary intellectuals with a conceptual framework by which to understand what had gone wrong with the once revolutionary and democratic republic

An implicit consequence of the approach taken in this chapter has been that simplistic uses of Veblen construing him as a theoretician who busied himself with making predictions should be problematized. One example of such construal can be found in Layton who additionally claims that "the evolution of Veblen's thought concerning engineers owed less to theory than to actual occurrences" (Layton 1962, p. 66), a position which the chapter has shown to be untenable. In the course of this study we have also observed a tendency among engineering education researchers and historiographers of engineering to reduce the complexity of Veblen's thought to a number of his provocative statements. This means that the theoretical system behind the claim has been neglected, with the result that a more balanced assessment of the critical potential of Veblen's theoretical system, and his key insights regarding the inherent contradictions of capitalism, have been lacking. In this respect not least his theory of corporation finance as presented in *The Theory of Business Enterprise*

[1] In establishing a trial balance we are indebted to Michael Spindler (2002, pp. 144–146).

should be seen as a robust analysis of current practices of corporation finance. By way of illustration it should be borne in mind that the collapse of the U.S. stock market in 2000 and its stagnation were accompanied "by news of financial fraud, the corruption of accounting standards, pie-in-the-sky profit projections, and the flow of false financial information" (Ganley 2004, p. 397).

References

Banks, J. A. (1959). Veblen and industrial sociology. *The British Journal of Sociology, 10*(3), 231–243.

Bell, D. (1963). Veblen and the new class. *The American Scholar, 32*(4), 616–618 620, 622–623, 626–628, 630, 632, 634, 636, 638. Available at http://www.jstor.org/stable/41209141. Accessed 23 Mar 2015.

Brette, O. (2003). Thorstein Veblen's theory of institutional change: Beyond technological determinism. *The European Journal of the History of Economic Thought, 10*(3), 455–477.

Camic, C., & Hodgson, G. M. (Eds.). (2011). *Essential writings of Thorstein Veblen*. New York: Routledge.

Cornehls, J. V. (2004). Veblen's theory of finance capitalism and contemporary corporate America. *Journal of Economic Issues, 38*(1), 29–57.

Davis, A. K. (1945). Sociological elements in Veblen's economic theory. *Journal of Political Economy, 5*, 138–149.

Dorfman, J. (1972 [1934]). *Thorstein Veblen and his America*. Clinton: Augustus M. Kelley Publishers.

Dugger, W. F. (1995). Veblenian instutionalism: The changing concepts of inquiry. *Journal of Economic Issues, 29*(4), 1013–1027.

Edgell, S. (1975). Thorstein Veblen's theory of evolutionary change. *The American Journal of Economics and Sociology, 22*(3), 267–280.

Edgell, S. (2001). *Veblen in perspective: His life and thought*. New York: M.E. Sharpe.

Edgell, S., & Tilman, R. (1989). The intellectual antecedents of Thorstein Veblen: A reappraisal. *Journal of Economic Issues, 23*(4), 1003–1026.

Ganley, W. T. (2004). The theory of business enterprise and Veblen's neglected theory of corporation finance. *Journal of Economic Issues, 38*(2), 397–403.

Gruchy, A. F. (1958). Veblen's theory of economic growth. In D. Dowd (Ed.), *Thorstein Veblen: A critical reappraisal: Lectures and essays commemorating the hundredth anniversary of Veblen's birth*. Ithaca: Cornel University Press.

Hake, E. R. (2007). Capital and the modern corporation. In J. T. Knoedler, R. E. Prasch, & D. E. Champlin (Eds.), *Thorstein Veblen and the revival of market capitalism*. Cheltenham: Edgar Elgar Publishing.

Hill, F. G. (1958). Veblen and Marx. In D. Dowd (Ed.), *Thorstein Veblen: A critical reappraisal: Lectures and essays commemorating the hundredth anniversary of Veblen's birth*. Ithaca: Cornel University Press.

Hodder, H. J. (1956). The political ideas of Thorstein Veblen. *The Canadian Journal of Economics and Political Science/Revue Canadienne d'Economique et de Science Politique, 22*(3), 347–357.

Hodgson, G. M. (1992). Thorstein Veblen and post-Darwinian economics. *Cambridge Journal of Economics, 16*(3), 285–301.

Hodgson, G. M. (2004). Veblen and Darwinism. *International Review of Sociology/Revue Internationale de Sociologie, 14*(3), 343–361.

Hugley, M. W., & Vidich, A. J. (1993). Veblen, Weber and Marx on political economy. *International Journal of Politics, Culture, and Society, 6*(4), 491–505.

Knoedler, J. T. (2007). Getting to the good life: Agents of change. In J. T. Knoedler, R. E. Prasch, & D. E. Champlin (Eds.), *Thorstein Veblen and the revival of market capitalism*. Cheltenham: Edgar Elgar Publishing, Inc..

Knoedler, J., & Mayhew, A. (1999). Thorstein Veblen and the engineers: A reinterpretation. *History of Political Economy, 31*(2), 255–272.

Knoedler, J. (1997). Veblen and technical efficiency. *Journal of Economic Issues, 31*(4), 1011–1026.

Knoedler, J., & Mayhew, A. (1994). The engineer and standardization. *Business and Economic History, 23*(1), 141–151.

Kranakis, E. (2010). Looking into the mirror of time: Reflections on the life and work of Edwin T. Layton Jr., 1928–2009. *Technology and Culture, 51*(2), 543–560.

Kline, R. R. (2008). Review: From progressivism to engineering studies: Edwin T. Layton's "The Revolt of the Engineers". *Technology and Culture, 49*(4), 1018–1024.

Latsis, J. (2010). Veblen on the machine process and technological change. *Cambridge Journal of Economics, 34*(4), 601–615.

Layton, E. T. (1962). Veblen and the engineers. *American Quarterly, 14*(1), 64–72 Available at https://www.jstor.org/stable/2710227. Accessed 13 June 2012.

Layton, E. T. (1971). *The revolt of the engineers: Social responsibility and the American engineering profession*. Cleveland: The Press of Case Western Reserve University.

Meiksins, P. (1988). The "revolt of the engineers" reconsidered. *Technology and Culture, 28*(2), 219–246.

Noble, D. F. (1977). *America by design: Science, technology, and the rise of corporate capitalism*. New York: Alfred A. Knopf.

Patsouras, L. (2004). *Thorstein Veblen and the American way of life*. London: Black Rose Books.

Rutherford, M. (1992). Thorstein and the problem of the engineers. *International Review of Sociology, 3*(3), 125–150 Available at https://doi.org/10.1080/03906701.1992.9971125. Accessed 18 June 2012.

Rutherford, M. (1998). Veblen's evolutionary programme: A promise unfulfilled. *Cambridge Journal of Economics, 22*, 463–477.

Spindler, M. (2002). *Veblen and modern America: Revolutionary iconoclast*. London: Pluto Press.

Stabile, D. R. (1986). Veblen and the political economy of the engineer. The radical thinker and engineering leaders came to technocratic ideas at the same time. *The American Journal of Economics and Sociology, 45*(1), 41–52.

Stabile, D. R. (1987). Veblen and the political of technocracy: The herald of technological revolution developed an ideology of "scientific" collectivism. *American Journal of Economics and Sociology, 46*(1), 35–48.

Stabile, D. R. (1988). Veblen's analysis of social movements: Bellamyites; workers, and engineers. *Journal of Economic Issues, 22*(1), 211–226.

Sweezy, P. (1958). Veblen on American capitalism. In D. Dowd (Ed.), *Thorstein Veblen: A critical reappraisal: lectures and essays commemorating the hundredth anniversary of Veblen's birth*. Ithaca: Cornel University Press.

Tilman, R. (1972). Veblen's ideal political economy. *The American Journal of Economics and Sociology, 31*(3), 307–317.

Tilman, R. (1973). Thorstein Veblen: Incrementalist and Utopian. *The American Journal of Economics and Sociology, 32*(2), 155–169.

Tilman, R. (1988). A comment on stabile's interpretation of Veblen and the engineers. *Journal of Economic Issues, 22*(4), 1247–1249.

Veblen, T. (1898a/2007). Why is economics not an evolutionary science. In T. Veblen (1919) (Ed.), *The place of science in modern civilization*. New York: Cosimo Classics.

Veblen (1898b). The instinct of workmanship and the irksomeness of labor. In T. Veblen (2013) (Ed.), *Essays in our changing order*. Edited by Leon Ardzrooni. Read Books Ltd Lightning Source UK, Ltd, Milton Keynes UK.

Veblen, T. (1899a). *The theory of the leisure class*. Oxford: Oxford University Press.

Veblen (1899b). Mr. Cumming's strictures on "The Theory of the Leisure Class". In T. Veblen (2013) (Ed.), *Essays in our changing order*. Edited by Leon Ardzrooni. Read Books Ltd. Lightning Source UK, Ltd, Milton Keynes UK

Veblen, T. (1901/2013). Industrial and pecuniary employments. In T. Veblen (1919) (Ed.), *The place of science in modern civilization*. Reprinted (2007). New York: Cosimo Classics.

Veblen, T. (1904/2013). *The theory of business enterprise*. Mansfield Center: Martino Publishing.

Veblen, T. (1906a/2007). The place of science in modern civilization. In T. Veblen (1919a/2007) (Ed.), *The place of science in modern civilization*. New York: Cosimo Classics

Veblen, T. (1906b/2007). The socialist economics of Karl Marx and his followers. In T. Veblen (1919/2007) (Ed.), *The place of science in modern civilization*. New York: Cosimo Classics.

Veblen, T. (1908). The evolution of the scientific point of view. In T. Veblen (1919/2007) (Ed.), *The place of science in modern civilization*. New York: Cosimo Classics.

Veblen, T. (1909). The limitations of marginal utility. In T. Veblen (1919/2007) (Ed.), *The place of science in modern civilization*. New York: Cosimo Classics.

Veblen, T. (1914/2006). *The instinct of workmanship and the state of the industrial arts*. New York: Cosimo Classics.

Veblen, T. (1919/2014). *The vested interests and the common man.* Mansfield Center: Martino Publishing.

Veblen, T. (1921/2009). *The engineers and the price system. Introduction by Daniel Bell.* New Brunswick: Transaction Publishers.

Veblen, T. (1923/2007). *Absentee ownership: Business enterprise in recent times: The case of America.* New Brunswick: Transaction Publishers.

Watkins, M. W. (1958). Veblen's view of cultural evolution. In D. Dowd (Ed.), *Thorstein Veblen: A critical reappraisal: Lectures and essays commemorating the hundredth anniversary of Veblen's birth*. Ithaca: Cornel University Press.

Steen Hyldgaard Christensen MA in Danish Language and Literature and the History of Ideas from Aarhus University, PhD in Engineering Education Research from Aalborg University. Until 2014 senior lecturer at Aarhus University. Since 2014 Adjunct associate professor at Aalborg University. He is lead editor and co-author of six edited volumes: *Profession, Culture, and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives* (Springer 2012), *International Perspectives on Engineering Education*: *Engineering Education and Practice in Context. Volume I* (Springer 2015), and *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context. Volume II* (Springer 2015). Besides he has co-authored *A Hybrid Imagination: Science and Technology in Cultural Perspective* (Morgan & Claypool Publishers 2011) together with Andrew Jamison and Lars Botin. In addition he has published a number of articles on engineering epistemology, culture and higher education. Current research interest: Dynamics in higher education restructuring, Thorstein Veblen, and the tension between engineering and business.

Bernard Delahousse MA in English Language and Literature, Faculté des Lettres de Lille, France. Ex-lecturer in English for Specific Purposes for Engineering students at Université Lille 1 Sciences et Technologies, France. Head of International Office at IUT "A" Lille 1 (1987–2004). Co-editor and co-author of three previous books resulting from international projects initiated and

coordinated by S. H. Christensen: *Profession, Culture and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009). Co-author of a further book coordinated by S. H. Christensen: *International Perspectives on Engineering Education: Engineering Education and Practice in Context. Volume I* (Springer 2015). Chief editor of *Les Langues Modernes*, the journal of the French Association des Professeurs de Langues Vivantes (APLV), 2007–2010, then co-editor 2011–2013.

Chapter 8
The Sons of Martha Versus the Sons of Mary: Forging Iron and Finding Gold in Engineering and Business Ideologies

Janis Langins

Abstract Rudyard Kipling, the bard of the Victorian British Empire, has a number of themes in his poetry that are closely aligned to the ideology of Veblen. In this chapter, I shall examine these themes in the context of an industrializing Canada where Kipling was invited to write a kind of Masonic ritual to serve as a professional ideology for Canadian engineers. Kipling enthusiastically accepted this invitation and the unique "Iron Ring" ceremony continues be a part of the graduation rites of Canadian engineering students. Kipling's "Sons of Martha" from his poem of that name, which serves as the core of the Iron Ring ceremony, could well have been an ode to Veblen's "Spirit of Workmanship". It appears to have resonated with engineers not just in Canada but in the United States as well and elicited a response (again in the form of a poem, called the Sons of Mary) from those who rejected the ideology implicit in the poem and adhered to a distinctly business ideology. I shall analyze and contrast these conflicting ideologies and attempt to identify the contradictions in both of them. Both contributed to forming the uneasy nexus between business and engineering that continued to evolve during the twentieth century.

Keywords Kipling · Veblen · Iron ring · Engineering professionalism

8.1 Introduction

Rudyard Kipling (1865–1936), the first Englishman to win the Nobel Prize in Literature, was one of the most popular authors of the late nineteenth and early twentieth century in the English-speaking world. In 1923 he was approached by Herbert Edward Terrick Haultain (1869–1961), a professor of mining engineering at

J. Langins (✉)
Institute for the History and Philosophy of Science and Technology, University of Toronto, Toronto, ON, Canada
e-mail: j.langins@utoronto.ca

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_8

the Faculty of Applied Science and Engineering at the University of Toronto to write a “Ritual of the Calling of the Engineer” intended to be an induction into the career of an engineer. It was to be a voluntary and informal part of graduation not just for practicing engineers and engineering students at Toronto but for all of Canada. Kipling responded quickly and the first ceremony took place in Montreal in April 1925 (Pavri 2000 and Haultain fonds, University of Toronto Archives). Indeed, both Kipling and Haultain dreamed that this ritual would be instituted in all parts of the British Empire as well. Their efforts bore fruit in Canada and the “Iron Ring” ceremony flourishes there to this day. The iron ring, made of rough-hewn iron (today more frequently stainless steel) is worn on the little finger of the working hand. It is awarded at a quasi-Masonic ceremony and still serves to identify engineers in Canada. Probably most wear it and it was commemorated with Canadian Post Office stamp in 2002.

In this chapter I intend to use the history of the Iron Ring ceremony to examine a period of change in engineering and the engineering profession in Canada as well as the United States. The late nineteenth and early twentieth century saw changes in engineering that made the ideology of the Iron Ring reflect an age that was disappearing when the ceremony was created. The influence of modern business as well as academic engineering education became increasingly important and even central in the ethos of North American engineers.

In spite of Kipling’s and Haultain’s wish to make the Iron Ring ceremony a feature of engineering education in all parts of the British empire, it received little notice outside of Canada. There has recently been some interest in the United States but the ceremony remains characteristically Canadian (Petroski 1995). Canada industrialized a generation after the United States according to the chronology of Walt Rostow but because of its close links with its southern neighbor many social, ideological, and institutional trends were similar in the two countries and the analysis presented here is applicable to North America as a whole (Rostow 1990).

It is not, however, applicable to other regions and other times. The culture of engineers is an old one and is coterminous with civilization itself. It has changed over time and has conformed to the societies of which it is a part. Although the stark comparison between engineering cultures of France and England in the nineteenth century needs to be nuanced and qualified, it is nevertheless clear that the dominant culture of French engineering, with its roots in an aristocratic and *dirigiste* society with a prominent place for military considerations, differed from that of English engineering, where an increasingly *laissez faire* economy provided a considerably more hospitable context for private enterprise. Antoine Picon has used the felicitous analogy of engineering as a continent (Picon 2004). Another and perhaps slightly more illuminating analogy would be seeing engineering as an archipelago in the ocean of human society. There are connections and interactions among the individual islands of the archipelago in this ocean but the islands are not the same. Their extent and topographies are different and the technological challenges and opportunities within them are different as well and elicit different solutions.

8.2 Two Sons of the Empire

Kipling and Haultain shared some distinctive similarities. Both were "children of the Raj". Born in British India, Kipling became the bard of the Victorian British Empire with his tales of the Northwest Frontier, *Kim*, and many other stories of adventure and conquest that excited the fancy not just of young boys but of their elders. They usually featured personages of quiet masculine heroism, with a spirit of self-denial and sense of duty to the Empire and the "lesser breeds without the Law" that the Empire ruled. Kipling wrote at a time when the engineer was associated with the triumphs of the Industrial Revolution. There are striking similarities between the characters of Kipling's heroes and some of Samuel Smiles' engineers and engineers appearing in some now forgotten American novels at the time (Smiles 1861; Ammons 1986). They are hard workers, unostentatious and retiring, trustworthy, scrupulously honest, eminently practical, and in love with their creations. They cut a poor figure among self-promoting, glib, and superficial men with fine social graces who often garnered the fruits of engineers' work.

Kipling is a man and a writer of many paradoxes. Much ink has been spilled by literary critics on the quality and meaning of his writing, his character, and the intentions that underlie his writing (Annan 1960). Although a detailed analysis of this is beyond the scope of this chapter some relevant points of his biography are worth mentioning. He did not come from a family of bureaucrats and soldiers who formed the backbone of the administration of the Raj. His father was an artist and architect who went to India purposefully to be the principal of a school of art where he wanted "to encourage, support, and restore native Indian art against the incursions of British business interests [and] sought in India to preserve, at least in part, and to copy styles of art and architecture which, representing a rich and continuous tradition of thousands of years, were suddenly threatened with extinction by an influx of new capital bent solely on immediate, commercial profit" (Cantalupo 1983). One of his mother's talented and beautiful sisters was married to Sir Edward Burne-Jones and Kipling spent school holidays in her home where he enjoyed the pleasures of access to the artistic society of pre-Raphaelites and others that provided much needed relief from the brutal ordeal of those sent "home" from India for their education in boarding schools run by martinets.

Kipling's praise for the servants of the Empire and its soldiers is not for the colonial administrators and senior officials who enjoyed its benefits but the subordinate officials and private soldiers who bore its hardships and fought its battles. Although an unabashed apologist for the Empire, he sounds a warning about the dangers of imperial hubris and smugness in his *Recessional* written at the height of the Empire during Queen Victoria's Diamond Jubilee in 1897. Although racism is visible in many of his writings there is also respect for brave men of other races who fought with and against the British army in India.

Haultain's father was a soldier who had served in India and married an Englishwoman born there and had retired with the rank of major-general to Canada where Haultain was born. He was one of the first students at the School of Practical

Science, the precursor of the Faculty of Applied Science and Engineering at the University of Toronto, as well as the first president of its students' undergraduate society. After graduation he had a distinguished career as a mining engineer that took him to Saxony, South Africa and other parts of Canada. Later he would go on to make important contributions to metals processing. He returned to Canada to become the professor of mining and mining engineering at his alma mater and his outsized personality is remembered at the Haultain Building of Mining Engineering named in his honor.

Haultain's view of engineering is conditioned by his own experience as a mining engineer and by the strong apprenticeship tradition in engineering education that can be contrasted with the Continental tradition of formal academic training. John Anderson Galbraith (1846–1914), first dean of Toronto's engineering faculty and Haultain's teacher, had been educated in mathematics and physics at university but had become an engineer in the traditional British way through apprenticeship on the job in building railways before he became a teacher. He never published any research papers in his field during his lifetime and came into conflict with his more research oriented colleagues in the University of Toronto because of his insistence that teaching was more important than research in the education of an engineer. For Galbraith, the value of a formal academic education was simply propaedeutic. It was to provide the engineer with the intellectual tools for a lifetime of learning his art but this art was to be learned in the field, not at the school desk. It was in the field that the student after graduation would become a true engineer (White 2000).

Haultain had spent years as a mining engineer in various parts of the globe returning to a university career only after a solid immersion into practice. Although the administration and management of the Iron Ring ceremony today is based in engineering faculties for practical logistical reasons, there is deliberately no formal connection with universities. The individual administering units of the Iron Ring are called "camps", a name redolent of the isolated mining camp. The aftermath of the ceremony has also been an occasion for student hijinks and bibulous rowdiness that Haultain easily tolerated and reflected once again the rough and tumble life of the mining camp and the isolated construction site. Yet these ungentlemanly aspects of engineering mores did not mean Haultain was content to surrender the perennial claims of engineers for status equal to that of the traditional dignified professions of law and medicine. The search for status is a major part of the motivation not only for the Iron Ring ceremony but also countless generations of technical workers. The invidious distinction between the liberal and mechanical arts that goes back to Classical Antiquity had been challenged ever more strongly over time and particularly during the industrial age. The prediction of Thorstein Veblen (1857–1929) for the coming triumph of the spirit of workmanship over the spirit of sportsmanship was but one aspect of this. The rise and proliferation of professional engineering societies was another. For Kipling and Haultain, the biblical figure of Martha, hitherto unappreciated, deserved to attain the respect she deserved even though she had been stoically content, after her rebuke by the Lord, to bear her burden in silence.

8.3 Martha and Mary

In writing the Ritual of the Calling of the Engineer, Kipling included in it one of his better known poems – "The Sons of Martha" – he had written in 1907 (See full text in Appendix A). The title alludes to an episode described in the Christian Bible in the gospel of Luke 10:38–42. Jesus has come to a village where he is staying with two sisters Mary and Martha. Martha is busy in the kitchen dealing with the practical details of serving their guest while Mary is sitting at the feet of Christ listening to his words. Martha erupts from the kitchen and complains – Mary should be helping as well. Christ rebukes Martha and declares that Mary has chosen "the good part".

In his argument that the cultural climate of the European Middle Ages was more technically oriented than hitherto believed, the historian of technology Lynn White analyzed this text of Luke and showed that it was interpreted in different ways over time in different Christian societies. In the early Christian era, Greek Christianity took the text literally. The spiritual Mary, attached to contemplating the eternal and otherworldly verities of religion was superior to the practical Martha bustling around to take care of the practical details of life on this earth. Very soon however, in Latin Christianity St. Augustine sees Martha and Mary representing two states of existence – life on this earth and life in heaven. We must be Marthas in our transient existence on earth before we will have the joy of becoming Marys in heaven. In the Middle Ages this attitude becomes even more pronounced. It is Martha who comes close to being the ideal and Christ is indulging Mary and asking Martha to be patient with her less mature sister. Martha is the one taking care of his needs and truly serving the Lord (White 1978, pp. 240–241). This view is quite contrary to the strict literalness of the text and is by no means as established as Lynn White believed. No less an ecclesiastical authority than Pope Francis recently admonished the members of the Roman Curia to avoid their "spirit of Martha-ism", the excessive busyness of those who immerse themselves in work and forget their spiritual vocation (The Irish Times 2014).

Kipling, however, sees Martha as heroine and model for the people, engineers prominently among them, who make the world function and serve their fellow humans. They bear their burden with quiet fortitude and they are often invisible in the kitchen serving to make the sons of Mary comfortable and prosperous.

It cannot come as a surprise therefore that Kipling was one of Thorstein Veblen's favorite authors. Moreover, according to his stepdaughter Becky Veblen, his favorite Kipling poem was "The Sons of Martha" (Tilman 2007, p. 160). This poem can surely serve as Veblen's ode to his "Spirit of Workmanship" (Veblen 1899, 1918). Veblen obviously was ready to ignore and forgive Kipling's robust imperialism and praise for the martial virtues that fit more properly with Veblen's "Spirit of Sportsmanship". Kipling suffered a literary eclipse after the horrors of World War I among progressive thinkers who rejected his imperialism, often equated with jingoism, his adoration of military virtues, often seen as blood thirstiness, and praise of an almost masochistic masculinity, often seen as a primitive machismo. There was more to Kipling than that and people like George Orwell, no lover of imperialism and its ideology, who trenchantly condemned Kipling's moral blindness to the evils of imperialism, saw this as well (Orwell 1942). So did Veblen, who felt attuned to the other side of Kipling.

8.4 Engineers and Kipling's Sons of Martha

In an anthology of readings in literature for civil engineers, the editor refers to the prestige of engineers at the time Kipling wrote "The Sons of Martha" and implies that he wrote in praise of civil engineers (Augustine 1989). But Kipling's view of the "engineer" needs further analysis.

Kipling's view of the engineer, although it leaves room for the planner, designer, and the manager also encompasses the labor aristocracy that actually gets its hands dirty and risks life in direct contact with construction and maintenance of technical artifacts. He specifically mentions those who work on transport, infrastructure, and electrical connections. When he writes "They finger death at their gloves' end where they piece and repiece the living wires" today's reader would probably think of an electrician not necessarily an electrical engineer. In English we still talk of the locomotive "engineer" – the person who operates the machinery rather than the one who designs or even builds it. In Kipling's lifetime the boundary between the "engineer" and "electrician" and between the "engineer" and the "machinist" was still somewhat fluid both socially and intellectually even though it was becoming more clear-cut. Both Kipling and Haultain had great respect for the skilled technical operator – as much as for his epigone – the engineer in our sense of the word. The engineer was functioning more and more in a technical context that was changing during the so-called Second Industrial Revolution – a context that was becoming more complex, more dependent on science, and included larger and larger corporate institutions.

In "McAndrew's Hymn", Kipling gives voice to the "Scots engineer" below decks who keeps the steam engines, which he loves in almost a personal way, running well:

> Then, at the last, we'll get to port an' hoist their baggage clear –
> The passengers, wi' gloves an' canes – an' this is what I'll hear:
> "Well, thank ye for a pleasant voyage. The tender's comin' now."
> While I go testin' follower-bolts an' watch the skipper bow.
> They've words for every one but me – shake hands wi' half the crew,
> Except the dour Scots engineer, the man they never knew.

Understandably for Kipling and his times, he sees the Sons of Martha as just that – sons – because for him the technical toilers are a masculine profession like the army where he also sings the praises of vitalism that attracted the criticism of many intellectuals such as E.M. Forster, especially after World War I (Lackey 2007). The robust horny-handed empiric who strains his muscles and sweats in the engine room while the passengers stroll on deck as in "McAndrew's Hymn" is also not the coolly cerebral planner, who conforms more closely to today's engineer. He represents animal energy, untiring care, and stubborn persistence. Although there is certainly an overlap in Kipling's time of his Sons of Martha with engineers of the day there is not a perfect identity. The rationality of Veblen's paragons of workmanship and Kipling's Sons of Martha, while related, is not quite the same. Conflating the "dour Scots engineer" with the engineering graduates of Canadian universities who were called the Sons of Martha was not entirely justified. As the century progressed it became even less justified.

8.5 The Struggle for Wealth

Attitudes to the acquisition of wealth are another area where there is some room for ambiguity in sketching the outlines of Kipling's thought. This can be seen in his poem "Mary Gloster" which complicates any facile analysis of Kipling's attitude to work, creativity, and wealth. In this dramatic monologue, a successful and wealthy shipping magnate calls his son to his deathbed and flagellates him for being a degenerate aesthete who has not traversed and does not appreciate his father's path to riches and respectability. He recounts how he started out with a single ship, how he partnered in a shipyard and used underhanded methods to acquire technical advantages and fraudulent insurance compensation, and how he ruthlessly competed with rivals, taking bold risks that others would not take, and how his business grew. Although not a robber baron of finance, here is a robber baron of industry, who despises the aristocratic social classes his son now has entered thanks to his father's wealth. The importance of practical and technical achievement is important but so are the instincts of competition and ruthless disregard for others and grim contempt for the weak. Only the memory of the beloved wife of his youth who died prematurely keeps a small spark of humanity under the aggressive and dominating exterior. We see a mixture of Veblen's spirit of workmanship and the predatory spirit of sportsmanship where the latter seems stronger. In the final analysis, however, this spirit of sportsmanship does differ from the one Veblen derided in that the ship owner competes in a world where commercial victory does depend to some extent on a new and expanding technology. Literary critics have differed on the merits of the poem and also on whether it represents a value judgement of Kipling. Does he take a more than usually sensitive view condemning the magnate who regrets his life's work and who hides remorse under the veil of bluster and recrimination or does he see the old pirate as someone who drives progress?

8.6 Technology and Business

The links between technology and business were particularly strong in Haultain's field of mining engineering. The Industrial Revolution had developed an unprecedented appetite for the materials that mining provided. Mining engineers roamed the world to find and extract them but needed the capital resources to do this. The financier and mining entrepreneur played a role that was as essential as the mining engineer's. The American Institute of Mining Engineers (AIME) founded in 1871 was one of the more flexible of the engineering professional societies that appeared in the latter half of the nineteenth century in its membership requirements. One did not have to be a trained mining engineer to qualify – being "practically engaged in mining, metallurgy, or metallurgical engineering" was sufficient and in practice it admitted many non-professionals and, according to Layton, served "the interests of the mining industry; professional development and welfare were not part of its program" (Layton 1971, p. 34). Rossiter Raymond, its president and long-time secretary from 1884 to 1911, although a polymath and an academically educated engineer himself, bragged that the membership included "common miners, laborers, mine foremen, and people that cannot spell". But he was even prouder to claim that 20% of America's most distinguished "captains of industry" were on its membership rolls" (Layton 1971, p. 94). Edwin Layton's work on the conflict between "business" and "professionalism" (linked in large measure with ideals of academic advancement and social responsibility) shows the AIME at the turn of the twentieth century to be the most business friendly professional engineering society in America.

8.7 Professional Engineers and Professional Businessmen

The first great engineering societies in the English-speaking world were those that grew out of the great projects in infrastructure such as the canal boom in England in the late eighteenth and early nineteenth centuries and the railway boom after 1830. In England, the Institution of Civil Engineers (ICE) founded in 1818 and the Institution of Mechanical Engineers (IME) founded in 1848 had as their first presidents the great engineers Thomas Telford (1757–1834) and George Stephenson (1781–1848), who were self-taught and served the joint stock companies that were usually necessary to mobilize the capital required for the massive infrastructure projects of this kind. Their technologies (with the notable exception of steam technology) had a long preliminary tradition and had evolved over centuries to bloom during the classical Industrial Revolution. The electrical industry only appeared in the nineteenth century and the new chemical industry that featured dyestuffs, pharmaceuticals, and explosives also appeared at this time when it also transformed traditional chemical industry. In America, the respective professional societies for these newer technologies appeared later – the American Institute of Electrical Engineers (AIEE) in 1884 and the American Institute of Chemical Engineers (AIChE) in 1908. Their common feature was new advanced scientific knowledge that was obtained in academic institutions and required a prolonged course of study.

It was about the same time that there appeared modern business schools described by Rakesh Khurana (2010). According to Burton Bledstein, an interesting feature of American professionalism that contrasted with English professionalism, was its association with higher education and universities (1976). Like other members of a rising middle class in America, both businessmen and engineers saw universities as an important element in legitimating professional status. But their professionalization had somewhat different characteristics in the context of the new corporations that appeared at the same time. Professionalization occurred in large, complex, dispersed, and multi-functional organizations whose business often involved advanced technology and where coordination and long term planning were required. This type of professionalization was rather different from that of a classical profession like medicine – whose Hippocratic oath was imitated in the Iron Ring ceremony – or the wave of new professions in America such accounting and funeral directors (Khurana 2010, p. 72).

Industries such as General Electric required massive amounts of capital and a new capitalist organization described by Alfred D. Chandler in his classic studies (Chandler 1977). Chandler's prime example is the railway where civil and mechanical engineers were the main technical actors. Another major characteristic of these novel corporations was the growth of a professional class of managers who came to acquire influence that became as great as that of financiers and owners of the corporations. This was the case of American chemical and electrical industries as well but the technologies involved were more complex and put a high premium on innovation – something that Willis R. Whitney, the first head of the research laboratory at General Electric, referred to as "our life insurance".

> Our research laboratory was a development of the idea that large industrial organizations have both an opportunity and a responsibility for their own life insurance. New discovery can provide it. (Reich 1985, p. 37)

David Noble cogently argued that the modern American engineer was a creature of modern corporate capitalism (Noble 1979). The reverse is also true. In significant ways the modern engineer created the modern corporation in his own image. Educational institutions that provided the personnel for the corporation were also molded to suit its needs. This union of engineering and business was not only extremely productive but came to be seen by most of Americans as normal and natural. The modern corporation and its servants overwhelmed more traditional engineering workplaces and training sites such as the machine shop (Calvert 1967). Although Taylorism got its start in the machine shop, it was ultimately absorbed and transformed by large corporations.

8.8 Engineers Go to University

The Morrill Land Grant Acts of 1862 to promote "the agricultural and mechanical arts" had a radical influence on the complexion of American engineering. Providing state support for higher engineering education, it released a flood of engineers on to the market place. Engineering became open to the poorer segments of the middle classes. A 1924 study indicates that even then 90% of 1st year engineering students had to work at least a year to earn enough to go to university to study engineering (Layton 1971, p .9). Moreover, the proliferation of engineering schools, coupled with the increasingly scientific, as opposed to artisanal emphasis, in their education, reinforced the role of university education for engineers. While only one-ninth of American engineers had a university education in 1870, that proportion had risen to one-half at the end of the World War I (Mann 1918, p.19). The expanding economy absorbed most of these engineers into the new corporate structures as employees more beholden to their employers than an earlier generation of more independently-minded West Point engineers with their military traditions and the independent consultants on the great infrastructure projects of the early Republic. To be sure, many of them were well-rewarded and achieved high positions in the new corporations and in times of economic boom the rapidly growing numbers of engineers were not dissatisfied with losing their former status of relatively autonomous practitioners of their art. This was all the easier since the elite engineers of the earlier period – typically the owners of machine shops, prominent consultants on infrastructure projects, and executives of railroads – were a numerically small and exclusive group.

The new corporate academically trained engineers not only had good employment prospects in a rapidly expanding modern economy but they rose to prominent positions in it. According to Noble, in the 1920s the presidents of General Electric, General Motors, Dupont, Singer, and Goodyear were former classmates at the Massachusetts Institute of Technology. In 1900, 7% of executives had engineering degrees, in 1920 the figure rose to 20%, and by 1964 a third of executives had engineering training (Noble 1979, pp. 310–315). It was probably around this time that there was a reflux of this trend – a phenomenon that is tied to a great extent to the increasing role of graduates of business schools. Even these graduates, however, had a significant number of engineer graduates among them – more than a quarter and an additional eighth from the hard sciences.

In spite of real similarities, these were no longer the Sons of Martha that Kipling and Haultain idealized. The Sons of Martha were “real” men, the sturdy, muscular, and independent Victorians Kipling admired and for which he was reproached and mocked (Oldenziel 1999). They were not the bland organization men certified for duty by schools. Iron in both a material as well as almost in a metaphysical sense formed the basis of their craft, not electromagnetic waves or organic chemicals. The symbolism of iron in Kipling’s work and the Iron Ring ceremony Kipling wrote is central. There is the Iron Ring itself as well as Kipling’s poem “Cold Iron” and the short story “Cold Iron” (Kipling 1910). The hammer, anvil, and iron chain play a prominent part in the ceremony and the chain could be seen as a link between the technologies of earliest times of engineering up to the present. Even the false legend circulating among Canadian engineers that Iron Rings were made from the collapse of the Quebec Bridge in 1907 as a reminder to engineers to be humble and to respect the inflexible demands of matter involve iron – the classical material of the First Industrial Revolution.

Kipling’s poem resonated strongly with engineers even as they were changing from the kind of Martha’s Sons that Kipling had in mind. University-trained engineers had adopted Kipling’s poem as their ode but were no longer content to be self-effacing and bear their burden humbly and quietly. Along with the struggle for status there was the claim on the public’s deference to their work. The gap between engineers as a profession and Kipling’s imagined Sons of Martha was growing. Indeed, about the time that Veblen wrote his *The Engineers and the Price System* (Veblen 1921) there had arisen a literary champion of the Sons of Mary, not Martha, and the new kind of engineer was adjudged to be among them.

8.9 The Sons of Mary Demand Their Part

This counterpoint to the "Sons of Martha" appeared in the New York *Tribune* and was reprinted in 1919 in the *Literary Digest,* a very popular magazine (eventually reaching a circulation in excess of one million) published by Funk and Wagnalls in 1919. It is worth noting that the demise of this magazine was triggered by a famous mistake it made during the presidential elections of 1936. The magazine had run an opinion poll that predicted the defeat of Roosevelt and its dismal result, compared to the more scientific statistical methods of George Gallup, in spite of the enormous size of the sample polled is attributed to the choice of sampled population – telephone subscribers, automobile owners, and the subscribers of the magazine, a well-heeled lot who could afford magazine subscriptions, automobiles, and telephones during the Great Depression. It therefore seems natural that the people who read the journal would have approved of the poem it published.

"The Sons of Mary" never had the literary quality of Kipling's "The Sons of Martha" and I have not been able to track down its anonymous author "G.S.B.". If Orwell thought that Kipling was a "good bad poet", G.S.B. can safely be classified as a bad poet. But his poem is an excellent reflection of the ideological issues it opposes to Kipling's view of the working engineer. (For full text see Appendix B). In the prefatory remarks to "The Sons of Mary", the editor of the *Literary Digest* indicates that the poem is a reply to Kipling and that at the present time (1919) it was most timely because it is the Sons of Mary who are the real heroes, contrary to what Kipling believed. The direct allusion to Kipling's "Sons of Martha" published a dozen years earlier (1907) and also reprinted in 1919 as part of a Kipling anthology (*The Years Between*) indicates that the author G.S.B. knew his audience was familiar with Kipling's poem and its sentiments. G.S.B. believed that unlike Kipling's heroes the Sons of Mary

… do not preach that their only duties are spreading dissension
  and going on strike
They do not teach that it's square and decent to scamp their
  work as they damn well like.
They aim to uphold a mind of fairness, not class suspicion
  and social strife.
They, too, must think of making a living – but they
  sometimes think of making a life.

And the Sons of Martha esteem this silly, convinced that
  Fortune will yield reward
To him that has the most brazen thorax, the lightest head
  and the strongest sword.
This, it seems, is the sum of their Credo – this is the way
  their reasoning runs:
"Let's force the birthright and seize the blessing, and lay
  the burden on Mary's Sons!

These stanzas perfectly reflect as well the contemporary patriotic effusions that had begun during the World War and had fused with the anti-Bolshevik hysteria of the Red Scare immediately after it. The fear of increasing trade union militancy during and immediately after the war was a natural complement of this. The heroes of Kipling were now pictured as troublemakers and disrupters of progress rather than its promoters. The poem draws a line between the working class and everyone else contributing to civilization. Among these are doctors, artists, writers and intellectuals, inventors, entrepreneurs. Significantly, however, also included among these respectable others are engineers. Although the format of the poem is clearly Kiplingesque, the message is radically opposite:

> The Sons of Mary in all the ages have dared the venture and
> taken the chance;
> They explore earth's riches and plan the bridges, invent the
> machinery, design the plants.
> It is through them that on every work-day the Sons of Martha
> have work to do,
> It is through them that on every pay-day the Sons of Martha
> get every sou.

Here the engineer is not the dour Scot invisible below the decks of the steamship: he is the ally of the entrepreneur and the capitalist on the upper deck.

One can fairly speculate that the publication of the poem in the November 1919 issue of the *Literary Digest* is also a response to Thorstein Veblen's articles on engineers and capitalism in *The Dial* that appeared in the same year and were published as a book *The Engineers and the Price System* in 1921. In the immediate postwar years and the aftermath of the Bolshevik revolution and its echoes in the Western world the revolutionary tone of Veblen's writings on engineers, as well as the economy in general, provoked anxiety not just among owners of capital but the middle classes as well.

8.10 Veblen's Engineers and the New Engineers

G.S.B.'s American engineers who "plan the bridges, invent the machinery, design the plants" were also drawing closer to their colleagues and fellow servants of the corporations – the managers – who were also becoming products of schools. They were both part of what John Kenneth Galbraith later dubbed the "technostructure" (Galbraith 1967). Engineers often became businessmen and businessmen often had to have respectable technical skills to manage modern corporations. They too could relate to a new "anti-Kipling" anthem. "The Sons of Mary" could be seen as a rebuttal not only to Kipling but also to Veblen.

Scholars are divided on their interpretations of Veblen's work. Some are puzzled that so perceptive and keen observer as Veblen saw engineers as a revolutionary class who would form a "Soviet of Technicians" that would lead to radical change in the United States. Edwin Layton argued that Veblen mistook the fermentation among engineers in the 1920s for revolutionary yearnings (Layton 1962). Instead, engineers were yearning for status and economic betterment within the large corporations for which they worked.

Others argued that Veblen had been carried away by the turmoil of unemployment, labor unrest and the Red Scare and had suddenly seen engineers are the vehicle for radical social change. Janet Knoedler and Anne Mayhew have convincingly refuted this (Knoedler and Mayhew 1999). They show that Veblen had assimilated engineers to the class of people he called "technicians" – those imbued with the "spirit of workmanship" who worked in "industrial" rather than "pecuniary" employments. Moreover, Veblen was acquainted with what engineers were writing and had been for some time – back to the turn of the century. His distinction between "Industrial and Pecuniary Employments" dates from that period.

Like Kipling, Veblen was much read and his ideas had resonance in the Progressive era. However, the Technocracy movement that was partially inspired by Veblen was a flash in the pan phenomenon that flared out with Franklin Roosevelt's election and the New Deal (Akin 1977). The professional engineering societies, which had as part of their ostensible aims the defense of engineers' autonomy and an occupational moral code began to be dominated by corporate engineers from the 1920s onwards. But there were a number of maverick and elite engineers such as Frederick Haynes Newell (1862–1931), the first director of the United States Reclamation Service, and Morris Llewellyn Cooke (1872–1960), director of the Rural Electrification Administration during the New Deal, but their attempts either to create competing engineering societies or to create – in Layton's words – a "loyal opposition" within the existing societies failed (Jackson 1993; Layton 1971). The rank and file of what was now an ever more numerous army of corporate engineers was not receptive to their ideas.

In the ASME where Cooke attempted to institute a new code of ethics the initial founders were elite engineers from what Monte Calvert calls the "shop culture". They were socially established and well to do engineers who either owned machine shops and family owned mechanical establishments or were connected with people who did. Traditionally they began their careers working in those shops and familiarizing themselves with the details of production. Frederick Winslow Taylor (1856–1915), the founder of "scientific management", is an example of this. They were not part of large corporate structures and did not rely on professional managers and financiers to run their businesses. During the period described by David Noble that saw the birth of a new corporate capitalism and a new kind of corporate engineer their influence receded or they were absorbed in the new institutions. The original founders and the leaders of the ASME gave way to engineers coming from the corporate world who had succeeded in it and accepted its business values.

The business engineering nexus they espoused was implemented in a number of ways. One was the sheer force of numbers. Engineers were the fastest growing occupational group in America.

The golden age for the application of science to American industry came from 1880 to 1920, a period which also witnessed the rise of large industrial corporations. In these 40 years, the engineering profession increased by almost 2000%, from 7000 to 136,000 members. The civil engineer was overshadowed by the new technical specialists who emerged to meet the needs of industry: by the mining, metallurgical, mechanical, electrical, and chemical engineers (Layton 1971, p.3).

The numbers of university educated engineers as well as the successful engineers who had ascended to high positions in corporations became a majority in engineering professional societies. As the main employers of American engineers they exercised a considerable influence in the curricula of engineering faculties. The non-technical options in the engineering curriculum, which most engineering educators believed were important to the well-rounded engineer, provide significant hints about what was considered important in addition to technical subjects for engineers. The idea of a free choice to make a smorgasbord of courses was one but not the only or even the most important one of the types of non-technical courses offered at American universities.

8.11 The New Skills of the New Engineers

One class of elective courses was the core humanistic subjects that were the essence of traditional liberal education gentleman. This was inspired by the attempt to penetrate into universities where engineering had the odor of trade and the mechanic arts. In Europe, with its distinct technical schools that were not part of the university system, this problem did not exist. But for some American engineers and engineering educators the role of a liberally educated gentleman was important both to fit into the university and the world outside to solidify a higher social status.

Others felt that the patina of gentility was superfluous and in any event would not provide the solid educational experience that only a complete course of humanistic studies could provide. Instead, they felt that engineers should acquire useful non-technical knowledge in areas that were more directly pertinent to their careers, where the role of management – always important – was both becoming even more important and changing in the new context of corporate engineering. They called for courses in economics, sociology, and psychology to plan production and manage subordinate workers. This was something engineers of earlier times did not have in their formal education, where the modern human sciences did not yet have a place and were not necessary for controlling workers in smaller and less complicated industrial institutions. But in the new type of corporations this knowledge was becoming increasingly important as an adjunct to technical knowledge.

Yet another stream of non-technical electives was intended to provide a knowledge of practical business and management skills – business and contract law, accounting, and finance. Again, this was increasingly useful for the new engineer in his new context. Variants and combinations of these additions to technical curricula became common in North American engineering curricula and currently Canadian and American accreditation boards require on average non-technical electives to make up a fifth of the engineering curriculum for certification of diplomas. The debate on their purpose and nature continues to this day and is actually becoming more acute as curricula become overloaded with technical material in an ever more rapidly advancing technology.

It is all too easy to see a stark opposition between modern business and engineering during the Progressive era. There were divisions both within business and within engineering. Progressivism itself was fueled by the fears and resentments of traditional businessmen who were threatened by the growing corporations. And many of the successful corporations had modern technology, engineers, and organized scientific research as a fundamental part of their nature. Among engineers, too, there was a divide between Kipling's humble technical workers who learned their trade by apprenticeship and experiencing the daily activity of industry and engineers emerging from universities who aspired to a higher status.

8.12 Conclusion

Both Kipling and Veblen had a nostalgic and somewhat unrealistic view of the techno-economic activity that was occurring during their lifetimes. This is not surprising because the changes in technology and the way it was managed were both profound and rapid – perhaps too rapid to be absorbed by contemporaries. Vaclav Smil has even argued that technological change in the late nineteenth and early twentieth century was more rapid and profound than the much touted computer revolution of our own time (Smil 2005). Moreover, the pursuit of wealth cannot be neatly separated from rationality and technical competence in the modern era. Technology and technologists had become a major economic factor. And this factor was not exclusively the domain of the Sons of Martha or the sturdy industrial workmen manipulated and dominated by Veblen's predatory "sportsmen".

Unlike the natural sciences whose aim is to study and understand nature, engineering's aim is to control nature according to the classic definition of Thomas Tredgold (1788–1829) that is still enshrined in its current charter: "Engineering is the art of directing the great sources of power in nature for the use and convenience of man" (Institution of Civil Engineers). Over time the meaning of "man" for whose convenience the great sources of power in nature were to be directed has evolved. In earlier times "Man" was embodied in the rulers of what Karl Wittfogel called the "hydraulic civilizations" that he argued led to the "Oriental Despotism" of Mesopotamia and the Pharaonic state of ancient Egypt where infrastructure, monumental architecture, and military technology were the main engineering projects (Wittfogel 1957). In early modern times, glorification and amusement of the ruling elite was important but increasingly other functions such as communications and industrial organization began to occupy a greater presence in the occupational profile of engineering (Misa 2004). In more recent times capital formation and economic profit loomed ever larger. In countries like France, where the more prestigious engineers were more closely integrated into the state apparatus and had been since the seventeenth century under an aristocratic regime, the rise of modern capitalist values made slower headway. But in America modern liberal corporate capitalism developed an organic alliance with technology and engineering and came to have a great influence on them.

Haultain, like Kipling, shared Veblen's disdain for "pecuniary" pursuits and the emphasis in the Iron Ring oath (or "obligation") stresses good workmanship, hard work, pride in technical excellence, and collegiality with fellow engineers (Ritual of the Calling of an Engineer). There is no mention of subservience to employers or maximization of profits. Yet the mining engineering professor Haultain was fully aware that mining engineers filled the vaults of financiers with gold and were dependent on financiers for investment to dig that gold. If the ideology of other American engineering societies was on the whole less overtly favorable to business interests than the AIME, business ideology was never absent and, as we have seen, was growing within these societies.

Kipling had an outdated concept of the engineer when he wrote the Iron Ring ceremony. In fact, his "Sons of Martha" were diverging, socially, occupationally, and ideologically from the engineers who pledged their "obligation" on "cold iron". The engineers Veblen thought were the "General Staff of Industry" and so vital to its functioning were already beholden in many (and understandable) ways to his detested pecuniary mindset. I believe he erred when he argued that industry was ruled by people who were driven exclusively by the irrational and short-sighted race for gain. He was wrong to think that rationality was one of the defining characteristics of engineers and it would lead them to revolt against the irrational inefficiency of owners of capital. The search for efficiency, as Jennifer Alexander argues, was not an exclusive characteristic of engineers even though they had introduced the concept into Western thought (Alexander 2008). The values of engineers who Veblen thought were so crucial to productive industry and ultimately a productive and just society had also permeated modern corporations and their management. Not just the managers but the owners were increasingly rational in the way engineers were. The more far-sighted owners of capital had learned that stability and rational management, not a buccaneering, irrationally competitive, and cutthroat drive for winner-take-all profits was more conducive for profits in the long run. The beginnings of Galbraith's "technostructure" were beginning to appear and the conflict between engineering and business ideologies was fading.

Haultain's Iron Ring ceremony is therefore not so much a rejection of modern corporate capitalism and its values but a rejection of the irrational capitalism of the Gilded Age and another defense of status for engineers. It asserts the social responsibility of the engineer and his right to be a privileged partner in a new economy that is based on technology as well as money. The ceremony's purpose is to create a "tribal spirit" among engineers that will enable them to take their rightful place in modern society and the economy. Whether the self-aware "tribe" would restrict itself to moving in step with business or be a loyal opposition was not something Haultain seems to have considered.

Appendices

Appendix A

The Sons of Martha: Rudyard Kipling (1907)

The Sons of Mary seldom bother, for they have inherited that good part;
But the Sons of Martha favour their Mother of the careful soul and the troubled heart.
And because she lost her temper once, and because she was rude to the Lord her Guest,
Her Sons must wait upon Mary's Sons, world without end, reprieve, or rest.
It is their care in all the ages to take the buffet and cushion the shock.

It is their care that the gear engages; it is their care that the switches lock.
It is their care that the wheels run truly; it is their care to embark and entrain,
Tally, transport, and deliver duly the Sons of Mary by land and main.
They say to mountains "Be ye removèd." They say to the lesser floods "Be dry."

Under their rods are the rocks reprovèd – they are not afraid of that which is high.
Then do the hill-tops shake to the summit – then is the bed of the deep laid bare,
That the Sons of Mary may overcome it, pleasantly sleeping and unaware.

They finger Death at their gloves' end where they piece and repiece the living wires.
He rears against the gates they tend: they feed him hungry behind their fires.
Early at dawn, ere men see clear, they stumble into his terrible stall,
And hale him forth like a haltered steer, and goad and turn him till evenfall.

To these from birth is Belief forbidden; from these till death is Relief afar.
They are concerned with matters hidden – under the earthline their altars are –
The secret fountains to follow up, waters withdrawn to restore to the mouth,
And gather the floods as in a cup, and pour them again at a city's drouth.

They do not preach that their God will rouse them a little before the nuts work loose.
They do not preach that His Pity allows them to drop their job when they damn-well choose.
As in the thronged and the lighted ways, so in the dark and the desert they stand,
Wary and watchful all their days that their brethren's ways may be long in the land.

Raise ye the stone or cleave the wood to make a path more fair or flat;
Lo, it is black already with the blood some Son of Martha spilled for that!
Not as a ladder from earth to Heaven, not as a witness to any creed,
But simple service simply given to his own kind in their common need.

And the Sons of Mary smile and are blessèd – they know the Angels are on their side.
They know in them is the Grace confessèd, and for them are the Mercies multiplied.
They sit at the feet – they hear the Word – they see how truly the Promise runs.
They have cast their burden upon the Lord, and – the Lord He lays it on Martha's Sons!

Appendix B

The Sons of Mary: **By G.S.B. (1919)**

The Sons of Martha have not to worry – of that their tetrarchs will take good care:
And they care not a whit for the Sons of Mary, what they must suffer or how they fare.
The Sons of Martha demand an increase (a favorite indoor game that they play):
They spout and they riot until they win it – and Mary's Sons are the 1ads that pay.

The Sons of Mary in all the ages have dared the venture and taken the chance;
They explore earth's riches and plan the bridges, invent the machinery, design the plants.
It is through them that on every work-day the Sons of Martha have work to do
It is through them that on every payday the Sons of Martha get every sou.

They say to the railways, "Be- ye fashioned". They say to the ships of the air, "Go, fly".
They train the youth and they heal the stricken; the tears of the mourner they help to dry.
They draft the maps and they paint the pictures; they carve the statue; the speech they speak –
While the Sons of Martha are seeking solely to do less labor for more per week.

The Sons of Mary their lives have given to fight the fever and purge the filth;
They graft the scion, they grow the blossom, they keep the fields of the world in tilth.
They write the book and they chant the poem, they make the music and dream the dream:
They to the Truth bear unselfish witness: they have the vision, they see the Gleam.

They do not preach that· their only duties are spreading dis-
sension and going on strike;
They do not teach that it's square and decent to scamp their work as they damn well like.
They aim to uphold a .mind of fairness, not class suspicion and social strife.
They, too, must think of making a living – but they some times think of making a life.

And the Sons of Martha esteem this silly, convinced that Fortune will yield reward
To him that has the most brazen thorax, the lightest head
and the Strongest sword.
This, it seems is the sum of their Credo – this is the way
their reasoning runs:
"Let's force the birthright and seize the blessing, and lay
The burden on Mary's Sons!"

References

Akin, W. (1977). *Technocracy and the American dream: The technocrat movement, 1900–1941*. Berkeley: University of California Press.

Alexander, J. (2008). *The mantra of efficiency: From water wheel to social control*. Baltimore: The Johns Hopkins University Press.

Ammons, E. (1986). The engineer as cultural hero and Willa Cather's first novel, Alexander's Bridge. *American Quarterly, 38*(5), 746–760.

Annan, N. (1960). Kipling's place in the history of ideas. *Victorian Studies, 3*(4), 323–348.

Augustine, J. (Ed.). (1989). *Sons of Martha: Civil engineering readings in modern literature*. New York: American Society of Civil Engineers.

Bledstein, B. (1976). *The culture of professionalism: The middle class and the development of higher education in America*. New York: Norton.

Calvert, M. (1967). *The mechanical engineer in America, 1830–1910: Professional cultures in conflict*. Baltimore: Johns Hopkins University Press.

Cantalupo, C. (1983). Rudyard Kipling. In D. E. Stanford (Ed.), *Dictionary of literary biography* (vol. 19) (British Poets, 1880–1914). Detroit: Gale.

Chandler, A. (1977). *The visible hand: The managerial revolution in American business*. Cambridge, MA: Belknap Press of Harvard University Press.

G.S.B. (1919). *Literary digest*. Current Poetry – The Sons of Mary. (8 November).

Galbraith, J. (1967). *The new industrial state*. Boston: Houghton Mifflin Haultain fonds, University of Toronto Archives.

Jackson, D. (1993). Engineering in the progressive era: A new look at Frederick Haynes Newell and the U.S. Reclamation Service. *Technology and Culture, 34*(3), 539–574.

Khurana, R. (2010). *From higher aims to hired hands: The social transformation of American business schools and the unfulfilled promise of management as a profession*. Princeton: Princeton University Press.

Kipling, R. (1910). *Rewards and fairies*. London: Macmillan.

Knoedler, J., & Mayhew, A. (1999). Thorstein Veblen and the engineers: A reinterpretation. *History of Political Economy, 31*(2), 255–272.

Lackey, M. (2007). Kipling's poems. *Journal of Modern Literature, 30*(3), 12–30.

Layton, E. (1962). Veblen and the engineers. *American Quarterly, 14*(Spring), 62–72.

Layton, E. (1971). *The revolt of the engineers: Social responsibility and the engineering profession*. Baltimore: Johns Hopkins University Press.

Mann, C. (1918). *A study of engineering education prepared for the Joint committee on engineering education of the national engineering societies*. New York: Carnegie Foundation for the Advancement of Teaching.

Misa, T. (2004). *Leonardo to the internet: Technology & culture from the Renaissance to the present*. Baltimore: Johns Hopkins University Press.

Noble, D. (1979). *America by design: Science, technology, and the rise of corporate capitalism*. New York: Oxford University Press.

Oldenziel, R. (1999). *Making technology masculine: Men, women, and modern machines in America, 1870–1945*. Amsterdam: University of Amsterdam Press.

Orwell, G. (1942). Rudyard Kipling. *Horizon*. February.

Pavri, V. (2000). The engineers' champion: Rudyard Kipling and the early history of the iron ring ceremony in Canada. Unpublished student 2000 paper, University of Toronto.

Petroski, H. (1995). The iron ring. (Iron ring ceremony for engineers). *American Scientist, 83*(3), 229 (4).

Picon, A. (2004). Engineers and engineering history: Problems and perspectives. *History and Technology: An International Journal, 20*(4), 421.

Reich, L. (1985). *The making of American industrial research: GE and Bell, 1876–1926*. New York: Cambridge University Press.

Rostow, W. (1990). *The stages of economic growth: A non-communist manifesto*. Cambridge, UK: Cambridge University Press.

Smil, V. (2005). *Creating the twentieth century: Technical innovations of 1867–1914 and their lasting impact*. New York: Oxford University Press.

Smiles, S. (1861). *Lives of the engineers, with an account of their principal works*. London: Murray.

The Irish Times. (Tuesday, Dec. 23, 2014). URL http://www.irishtimes.com/news/world/pope-francis-s-broadside-leaves-roman-curia-shocked-and-awed-1.2047943. Accessed 22 Oct 2015.

Tilman, R. (2007). *Thorstein Veblen and the enrichment of evolutionary naturalism*. Columbia: University of Missouri Press.

Veblen, T. (1899). *The theory of the leisure class*. New York: Macmillan.
Veblen, T. (1918). *The instinct of workmanship and the state of the industrial arts*. New York: B.W. Huebsch.
Veblen, T. (1921). *The engineers and the price system*. New York: Viking Press.
White, L. (1978). Cultural climates and technological advance in the Middle Ages. In *Medieval religion and technology* (pp. 217–253). Berkeley, University of California Press.
White, R. (2000). *The Skule story: The University of Toronto Faculty of Applied Science and Engineering, 1873–2000*. Toronto: University of Toronto Press.
Wittfogel, K. (1957). *Oriental despotism: A comparative study of total power*. New Haven: Yale University Press.

Janis Langins Emeritus professor of history of technology at the Institute for the History and Philosophy of Science and Technology at the University of Toronto, where he also received his doctorate in the history of science and technology. Previously he graduated from McGill University with a Master's degree in chemical engineering. His research interests have been mainly in the social history of engineering, more specifically in the history of the military engineering corps of Old Regime France. In the course of teaching at the Faculty of Applied Science and Engineering (as well as the Faculty of Arts and Science) at the University of Toronto he became interested in the history of technical education, Thorstein Veblen, and the dialectic in America and elsewhere between engineering and business.

Chapter 9
The Entrepreneurs and Engineers in China: The Situation in the Long 1980s

Nan Wang and Bocong Li

Abstract Entrepreneurs and engineers are two kinds of members of the engineering community. Among the characteristics of entrepreneurs and engineers are that they make appropriate and fast responses to changes in technological development, the economic system, the system of law, ideology, and social tradition. This phenomenon was prominent in China during the long 1980s. In this chapter, the long 1980s refers to the period from 1978 to 1992, in which the transformation from a planned economic system to a market economic system took place in China. Under the transformation of the economic and ideological system, the Chinese engineering community, especially entrepreneurs and engineers experienced tremendous changes. Specifically, entrepreneurs disappeared before the 1980s and then reemerged, and engineers who had been bound or restricted, evolved into a special kind of engineers, Sunday Engineers. This chapter will first briefly introduce the meaning of the concept of the long 1980s. Then it will focus attention on the characteristics of Chinese entrepreneurs and engineers during the long 1980s.

Keywords Engineering community · China · Economic system reform · Entrepreneur · The long 1980s

9.1 Introduction

In modern society, while scientific activity is carried out by the scientific community that consists of scientists, engineering activity is carried out by the engineering community that consists of entrepreneurs, engineers, workers, managers, investors, and other stakeholders (Li 2010, p.7). It is obvious that the scientific community is a homogeneous one while the engineering community is a heterogeneous one. Different kinds of members of the engineering community play different roles in

N. Wang (✉) • B. Li
College of Humanities and Social Sciences, University of Chinese Academy of Sciences, Beijing, China
e-mail: wangnan@ucas.ac.cn; libocong@ucas.ac.cn

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_9

engineering activity, and each kind plays a particular, irreplaceable role in the engineering community. However, it should be noted that the particular structure of the engineering community and the role that a particular kind of member plays are by no means set in stone. With changes in technological development, the economic system, and the system of law, ideology, social tradition in different historical periods and social environments, the structure and function of the engineering community will inevitably change accordingly. Chinese entrepreneurs and engineers experienced a great change in the long 1980s when the reform of the economic system, or more precisely the transformation from a planned economic system to a market economic system, took place in China. This chapter will focus on the situation of the Chinese entrepreneurs and engineers in the long 1980s.

9.2 China's Economic System Reform in the Long 1980s

There are some terms used to describe multiple years: a decade is a period of 10 years; a century is that of 100 years, and a millennium is 1000 years. However, Fernand Braudel, a French historian and educator, coined a term "le long seizième siècle" (the long sixteenth century) in his 1949 book *La Méditerranée et le monde méditerranéen à l'époque de Philippe II* (The Mediterranean and the Mediterranean World in the Age of Philip II). According to him, "the long sixteenth century" refers to the period from 1450 to 1640, in which the modern world-system originated (Wallerstein 1979, p.37).

Under the influence of Fernand Braudel's concept, Eric Hobsbawm, a British Marxist historian and author, termed the period between the years 1789 and 1914 as "the long nineteenth century" and laid out the analysis in his best-known trilogy *The Age of Revolution: Europe, 1789–1848* (1962), *The Age of Capital: 1848–1875* (1975) and *The Age of Empire: 1875–1914* (1987). Later, in his 1994 sequel to the above-mentioned trilogy *The Age of Extremes: The Short Twentieth Century, 1914–1991* he promoted the concept of "the short twentieth century", starting with World War I and ending with the dissolution of the Soviet Union in 1991.

These terms "the long century" or "long centuries" referred to the time-periods that sprawl elastically beyond the boundaries of years ending in double zeros. Also the starting and ending points are specific events with important historical significance. Following these examples, this chapter will define "the long 1980s" to denote the period which begins in 1978 with the 3rd Plenary Session of the 11th Central Committee of the Communist Party of China (CPC), and ends with the South Tour Speeches by Deng Xiaoping in 1992.

The long 1980s has special significance in the history of China. From 18th to 22nd December, 1978 at the 3rd Plenary Session of the 11th Central Committee of the CPC, it was announced that the "Reform and Opening Up" policy had come into force, which set China on the course for nationwide economic reforms from the planned economic system to the market economic system. The planned economic system had resulted in many theoretical and practical difficulties since the People's

Republic of China (PRC) was founded in 1949. Some scholars proposed to implement a market economy. However there were also many scholars who held a negative attitude to a market economy due to political ideology. Fierce controversies resulted in society and the academic field. These debates involved many aspects, such as the forms of public ownership, the role of non-state-owned enterprises, and the intellectual's second-job employment, but they mainly focused on the relationship between the market economic system and socialism. These debates, with strong ideological overtones, profoundly affected many aspects of the country, and some people such as entrepreneurs and engineers paid a heavy price.

After Deng Xiaoping, the paramount leader of China from 1978 to 1989, made his famous south China tour in 1992, the answer to these debates was clarified. Deng Xiaoping inspected such southern cities as Wuchang, Shenzhen, Zhuhai and Shanghai from January 8 to February 21 and emphasized that "having more planning, or more market, is not the essential distinction between socialism and capitalism. A planned economy is not equivalent to socialism, for capitalism also has planning. A market economy is not equivalent to capitalism, for socialism also has market. Both planning and market are simply economic instruments" (Zhu et al. 2009, p.517). His speech offered the answer to a series of important theoretical and conceptual questions, and played a crucial role in guiding and accelerating China's reform and opening-up, as well as building socialism with Chinese characteristics.

9.3 The Situation of Chinese Entrepreneurs in the Long 1980s

9.3.1 A Brief Review on the Definition of the Entrepreneur

The concept of the entrepreneur is credited to Richard Cantillon, an Irish economist of French descent, who promoted the concept in his 1755 book *Essai sur la Nature du Commerce en Général* (Essay on the Nature of Trade in General). He described an entrepreneur as "a person who pays a certain price for a product and resells it at an uncertain price, making decisions about obtaining and using the resources while consequently admitting the risk of enterprise" (Carvalho 2015, p.90).

Around 1800, Jean-Baptiste Say, a French economist, described the entrepreneur as one who "shifts economic resources out of an area of lower and into an area of higher productivity and greater yield" (Johnston 2000, p.115). The difference between Cantillon and Say is that the former regarded the entrepreneur as a risk-taker and the latter predominately considered the entrepreneur a "planner" (Brewer 1992, p.51). The term entrepreneur became well-known due to the work of the Austrian-born American economist and political scientist Joseph Alois Schumpeter in the 1930s. According to him, an entrepreneur is a person who is willing and able to convert a new idea or invention into a successful innovation, or an entrepreneur is an innovator.

There are different opinions about the definition of the entrepreneur even today, but it is widely accepted that the entrepreneur plays a key and crucial role in modern economic growth, and in engineering development. Regarding the entrepreneur's position and function within the engineering community, Li Sanhu, a Chinese scholar, stated that an entrepreneur is a practical organizer or manager in engineering whose work is a compound of innovating new products, services or processes, identifying and grasping business opportunities, organizing and managing resources, creating wealth, and taking risk (Li 2010, pp. 142–143).

9.3.2 The Emergence and Initial Growth of an Entrepreneurial Class

Within China, the role of the entrepreneur was rarely spoken of, and was even a pejorative term according to Chinese academic and public opinion before the long 1980s. This was at a time when the role of the entrepreneur attracted the positive attention of society in the western world. The origins and functions of the Chinese entrepreneur in the modern history of China were regarded as a marginal field of study by the majority of Chinese scholars. It is at the beginning of the twenty first century that some Chinese writers began to pay attention to the role of entrepreneurs in China. Wu Xiaobo, a Chinese financial writer and publisher, used the phrase "To find the missing class" as the preface title to his book *Die dang yi bai nian: Zhong guo qi ye jia 1870–1977* (One hundred years of twists and turns: Chinese Enterprises 1870–1977). He said his work was intended to "provide a logical way to this-worldly people who are looking for direction, along a forgotten perspective all the time, with his trilogy of history of Chinese enterprises" (Wu 2012, Preface).

Actually the reason for the absence of an entrepreneur class in China dates back to ancient times. Traditionally, there were four major classes in the Chinese society, a distinction that was clearly formulated as early as the late Zhou dynasty (770–256 BCE) in terms of the *si min*, literally "four peoples", meaning "four categories of people". In descending order of prestige, they are *shi* (gentry), *nong* (farmer), *gong* (artisan), and *shang* (merchant). The original version of this classification is said to appear in the *Guanzi*, an encyclopedic compilation of different Chinese philosophical schools, named after the seventh century BCE statesman and philosopher Guanzi (2001, p.123). This constitutes explicit recognition of the primacy of agriculture over the other two nonintellectual activities as supplying the basic food needs of the Chinese society. Agriculture is described as "the root or basic" class for governing the country, and commerce as "the branch or secondary" class. Accordingly, "farmers" and "scholars", who were gentlemen, farmers, landlords, and thus also tied to the land, are the most honorable classes. "Artisans" and "merchants" are of lower social status.

"From the eighteenth century onwards", according to Marie-Claire Bergere, because of the economic revolution of the middle ages in China, "the merchant class had enjoyed a renewal of prosperity and prestige, evidenced by the increase in its regional and professional guilds" (Bergere 2008, p. 725). However, the modern Chinese enterprise and entrepreneur class did not emerge in China before the second half of the nineteenth century. Leaders of the Chinese political and intellectual elite in the Qing dynasty began to launch the Westernization Movement from 1860s to 1890s and to borrow industrial knowledge from the West in order to build a stronger China, after the defeat in the Opium Wars (first in 1839–1842 then again in 1856–1860). Various western technologies were introduced into the Chinese society, and modern military and civil enterprises were established as well. Among these modern enterprises, new kinds of merchants with entrepreneurial functions emerged.

The Westernization Movement ended in failure and the Qing dynasty collapsed in 1912, but the slogan of "self-strengthening" became the ambitious ideal for successive Chinese governments. In order to achieve this grand goal, the administration did its utmost to promote the development of modern industry and enterprise in China. In this context, the entrepreneur class emerged and gradually grew from 1912 to 1949.

9.3.3 The Missing Entrepreneurial Class in 1950s

With the founding of the PRC on October 1, 1949, the Chinese society entered into a new phase of socialist construction and transformation, which was a period of transition to a socialist planned economy system. The CPC put forth the General Line for the Transition Period on June 15, 1953 based on the Soviet-style, as the Soviet Union was the primary external political influence on the new PRC government. According to the General Line, the administration's general task for the transition period was "to gradually accomplish the country's industrialization along with the socialist transformation of agriculture, handicrafts and capitalist industry and commerce (short for Three Transformations) over a relatively long period of time". In short, it aimed to set up a socialist state-owned economy as the basis of the national economy.

The socialist construction and transformation was finished during the First Five Year Plan (1953–1957). It was much earlier than the initial expectation of 18 years, but quick action without a deliberate plan had some serious consequences for the national economy. Prior to the Three Transformations, there were five kinds of economic components: a state-owned economy, a co-operative (and collective) economy, the individual economy of peasants and handicraftsmen, a private capitalist economy, and a state capitalist economy. Among these the state-owned economy was dominant. However, at the end of the First Five Year Plan, the economic components gradually tended to be single components, i.e. state-owned or co-operative collective economy. Statistically, in 1957, 97.5% of peasants joined the agricultural production cooperatives, all private industry became joint public private operation, and the private sector only occupied the 0.1% and 2.7% of wholesale and retail sales respectively (Liu and Dong 1999).

In the following years, the first major event to happen was the Great Leap Forward, an economic and social campaign by the CPC that took place from 1958 to 1961. This event was followed by the Great Proletarian Cultural Revolution, a sociopolitical movement launched by CPC chairman Mao Zedong, and which lasted from 1966 to 1976. Both events were intended to strengthen and improve the ideological control over economic and social development. As a result a situation had emerged in which the state blindly sought the most pure form of a state-owned economy and eliminated all other economic components. It is reported that state-owned enterprises accounted for 77.6% of the country's total economy, the collective economy accounted for 22.4%, and the private economy scarcely existed (ibid).

Based on the planned economic system with a single public ownership economy, there was a highly centralized, unified and planned managerial system. In this system, enterprises were not the independent economic entity any more, and the directors of state-owned and collective enterprises could not make decisions independently as real entrepreneurs, but had to act in obedience with the national plan and arrangements. This phenomenon was called "the missing entrepreneur class in China" by some Chinese scholars. In this sense, one of the most important features of the socialist planned economic system was that of a special engineering community, one without entrepreneurs who ought to play the most dynamic and innovative role, and who also are the primary power behind the development of engineering and the economy.

9.3.4 The Rebirth of the Entrepreneurial Class in the Long 1980s

The transformation from the planned economic system to the market economic system in the long 1980s provided a good social environment for the rebirth of the entrepreneur class in China. In May 1992, the National Committee for Economic System Reform issued a Proposed Regulation on the Limited Liability Company, and an Interim Regulation on the Company Limited by Shares, which marked a turning point in the history of Chinese enterprise. Under the new circumstances, the whole country was experiencing a new breed of entrepreneurs.

Regarding the definition of entrepreneur, there are two views. Some scholars hold that only a few of people deserve the title of the entrepreneur, and they further believe that there is no entrepreneurship in the majority of enterprises. But others suggest that the founders of most small-, and medium-sized enterprises should be regarded as entrepreneurs. The latter opinion seems to be the more plausible. Actually, more than 90% of enterprises are small-, and medium-sized. Their value and role to the economy and society should not be underestimated. To a certain extent they reflect the essential features of enterprises more than large-sized ones. In the view of Justin Longnecker large-sized enterprises are institution-oriented, whereas the small- and medium-sized ones are entrepreneur-oriented (Zhu 2004, p.74–75).

The latter opinions can also explain the rebirth and growth of the new Chinese entrepreneur class in the long 1980s. With the tremendous policy support for the development of enterprises, the small-, and medium-sized enterprises, most of which were non-state-owned, gradually boomed. It is thought that the essential features of the entrepreneur are those of innovation and risk-taking. The risk-taking was especially prominent for Chinese entrepreneurs in the long 1980s, because they had to take dual risks. One risk comes from the market, which is common for all entrepreneurs in the world, and the other risk comes from changes in law, policy and ideology within China. The latter is even more acute under certain circumstances. It is one of the most prominent features of the Chinese entrepreneur class in the long 1980s.

The majority of Chinese entrepreneurs in the long 1980s were in charge of private enterprises. They sprang from three sources. The first source came from those who were self-employed, or were intellectuals who resigned from cadres and went into business. Through enlarging their businesses, they became the entrepreneurs of small-, and medium-sized enterprises, and a few of them also of large ones. At the same time township and village enterprises, which are market-oriented public enterprises under the purview of local governments based in townships and villages, were transformed. In considerable numbers these turned into private enterprises, which resulted in the second source of entrepreneurs. In a similar manner, the third source of entrepreneurs was the result of transforming state-owned enterprises into private enterprises.

The entrepreneurial class in the long 1980s differs from the earlier traditional merchant class and the entrepreneurial class in China in the period from the second half of the nineteenth century to the first half of the twentieth century. Many entrepreneurs have higher social status, which has brought the entrepreneur class prosperity and prestige. Chen Dongsheng, a Chinese well-known entrepreneur, noted that the central characteristic of the [new] entrepreneur class is that the majority of its members used to be the mainstream class of the society, given their previous work in government offices or research institutes. They began to agree with business that business should be seen as one of the best choices on the level of values. This meant that the mainstream elite could enter freely into business. (Chen 2008)

After the economic transformation the functional role of leaders of state-owned enterprises began to change. Under the market economic system, new competitive enterprises with various ownerships entered in the market. The state-owned enterprises needed to learn how to face serious competitive threats. Meanwhile, these state-owned enterprises also had to gain the status of “navigator” due to their vital importance to the nation’s economy and the people’s livelihood. All these required the leaders of state-owned enterprises to effectively become entrepreneurs in some degree.

9.4 The Situation of Chinese Engineers in the Long 1980s

9.4.1 The Engineers' Special Position in the Engineering Community

There are both general and narrow conceptions of the engineer. For example, in *Geschichte des Ingenieurs: Ein Beruf in sechs Jahrtausenden* (A History of the Engineers: A Vocation during Six Millennia) (2006), Walter Kaiser and Wolfgang König define the engineer from a general point of view. According to such books, those who engage in the design of new products, technology and processes, and are responsible for technical work in the production process are regarded as engineers. This definition gives us a portrait of engineers' technical ability, their social role and function. On the other hand, with engineering professionalism, the engineer has developed into a highly professional career. This requires both professional education and professional certification, which is at the core of a narrow definition of the engineer. Roughly speaking, the general conception of the engineer can be applied to similar engineers in ancient times, while the narrow one to engineers in modern times only. It should be noted that it is difficult to comprehensively understand the functions, positions and role of the modern engineer.

From a technical point of view, as a member of the engineering community, engineers play a unique and important role, especially a design and key technical role in modern engineering activity. But it is hard to sum up the function and position of the engineer from a management perspective, or specially, at the angle of mutual relationship among the various members of engineering community. For example, when contradictions and conflicts come out between the investors and workers or between workers and managers, engineers usually find themselves entangled in a dilemma regarding which side to be on. This situation is aptly described in the following quotation of Professor Sharon Beder who says: "The position of engineers, partially as labour and partially as managers, prompted Herbert Shepard to call engineers marginal men; part scientist and part businessmen, sharing values and ideologies with both camps" (Beder 1998, p.25).

Furthermore, there is a variety of classifications of engineers according to their social and practical function (Li 2010, p.57–58). Gordon S. Brown, a professor of electrical engineering at MIT, divided engineers into four types: engineer-scientist, innovation engineer, field engineer, and technical planning and management engineer. Some European scholars proposed to divide engineers into three categories: theoretical engineer, contact engineer, and practical engineer. In Russia, engineers used to be classified into three categories: production engineer, research and design engineer, and general engineer.

Based on these classifications, engineers' multiple special essences and functions in the engineering community can be roughly summarized in terms of the following aspects (ibid., p. 52). Firstly, engineers are usually regarded and accepted as the technical authority of the engineering community, and thus engineers work as the designers of engineering projects, for they have the relevant technical knowledge and practical experience. They also have the ability to put forward and implement a feasible design. Meanwhile, engineers must work in engineering practice as the technical managers to solve the relevant organizational, administrative, and social problems. Engineers often must act to select the best among different solutions under existing conditions, and to put this solution into effect in the construction process. Generally engineers solve not only the technical problems but also many other relevant but non-technical problems.

9.4.2 The Emergence and Initial Growth of Modern Engineers

The term engineer is an exotic word in China. During the Westernization Movement at the second half of the nineteenth century, the Chinese began to translate the term "engineer" as *gong cheng si* or *gong cheng shi*. *Gong cheng* means engineering, and *si* names an official of the Ministry of Works who administers the standard weighing apparatus or measuring method in construction. *Gong cheng si* was initially applied to the western engineers who came to China, and then those Chinese ones who had the educational background in the West. However, the widely used term is *gong cheng shi*. *Shi* refers to a master as a noun, and to teach as a verb. Obviously, the two terms of translation respectively emphasize different aspects of functions and the role of the engineer as a member of engineering community. In 1912 Zhan Tianyou (Tien Yow Jeme as he called himself in English), a pioneering Chinese railroad engineer educated in the United States, founded *Zhong hua gong cheng shi xue hui* (the Chinese Institute of Engineers), the first engineering professional organization. Since then *gong cheng shi* became the regular translation of the word "engineer" into Chinese language.

In contrast to the variegated development of Chinese entrepreneurs, engineers went through a relatively stable growth. Artisans were seen as men of inferior status and lesser significance during ancient times, as described in *Guan zi* in the preceding part of this chapter, but this phenomenon changed very much when the second half of nineteenth century came. The Westernization Movement aimed to build a prosperous and powerful country, and it promoted the dual import of western science and technology, as well as engineers.

At first, engineers in China mainly consisted of western engineers who worked in the country. This is because the cultivation of native engineers needed a long period of time but hiring western engineers could serve the purposes of the moment, or short term needs. At the beginning of the twentieth century, when more and more Chinese returned to the country after having completed their studies in technological colleges or internships in a company abroad funded by the Qing government, the native engineering community gradually grew in the early twentieth century.

These native engineers plunged themselves into engineering construction and made many outstanding achievements. For example, from 1905 to 1909, the *Jingzhang* Railway (Beijing to Zhangjiakou) was built, which is the first railway designed and constructed by Chinese personnel. Zhan Tianyou was the designer and the Chief Engineer of the *Jingzhang* Railway, and later he was elected as a member of the North British Academy of Arts and also the American Society of Civil Engineers in 1909. In 1912, he founded the first engineer's institute, which used to be one of the largest academic bodies in the whole country. This Institute not only received the native engineers' approval and favorable comment, but also raised engineers' prestige and status.

Against this background, engineering education thrived, and more young people were engaged in engineering careers. Before the Republic of China was founded in 1912, there were 14 engineering schools which mainly aimed to train practical engineering talents. The Republic of China continued to promote engineering education in order to strengthen the nation by engaging in industry. Even during the Anti-Japanese War (1937–1945), the development of engineering education did not slow down due to the urgent need for engineering personnel. As an example, in 1945 immediately after the war the numbers of students enrolled in engineering was 15,200, which was double the number of 6989 enrolled in 1936 (Jin 2012, p.38).

9.4.3 A Special Form of Engineers in the Long 1980s: Sunday Engineers

The system of unified allocation of the labor force was introduced to north-east China in early 1949 in order to deal with scarce specialized skills of strategic significance for the planned economy. At the Conference of Directors of the National Labor Bureau held by the Ministry of Labor in May, 1955, it was decided to set up a unified recruitment and allocation system for the labor force for all sectors of the national economy.

At the end of 1956, the state was in charge of the employment for state-owned and joint state-private enterprises, as well as for the students of colleges and universities, and for urban demobilized soldiers. It ultimately became the employment and allocation system for centralized labor (including engineers). In this system the government undertook the task of arranging employment for the additional urban labor force every year, by way of allocating them to enterprises and institutions with a uniform recruitment approach.

Under this circumstance, some engineers were slack in their approach to work because they thought they already had a permanent income which would never be lost whether they worked hard or not. Others could not fully realize their special skills since approval was needed by higher authorities if they wanted to change jobs. Accordingly, talent flow was blocked, and skilled personnel had low income.

The limitations and deficiencies of the employment system of centralized labor allocation were apparent in its practice, but the Great Leap Forward and the Great Proletarian Cultural Revolution interrupted the government's attempt to make an adjustment. Before the long 1980s, the number of scientific and technological personnel was more than eight million, but almost one third had nothing to do.

The transformation from the planned economic system to the market economic system in the long 1980s was carried out initially in rural areas. The implementation of the household contract system greatly raised productivity. It provided the market with not only non-agricultural production, but also a large rural labor force by relieving people from work on the land. In such a situation the township enterprises grew at a very rapid rate.

The greatest problem for the township and village enterprises was lack of technical personnel. An important and effective method was inviting the technicians and engineers who worked in the urban enterprises or scientific institutions to help, and paying them according to the quantity of work (Rui 2006). The technicians and engineers in urban areas could only come to the township and village enterprises on Saturday when they were off duty. They then spent Sunday in their engineering work vocation, and returned to their employment unit on Monday morning. This special social phenomenon was called Sunday Engineers.

From a practical point of view, Sunday Engineers was a clear win-win result for both engineers and the township and village enterprises. It provided enterprises with urgent and required technical staff and promoted the production of the enterprise. Meanwhile, engineers found new possibilities to utilize their professional knowledge and they earned extra money. In those days, the engineers' monthly salary was usually 50–60 Chinese dollars, but by working on a Sunday an engineer could get paid around 100 Chinese dollars.

However, Sunday Engineers were at great ideological risk. At that time, the law did not state clearly whether technical personnel could take on a second job in addition to their full-time job. People's views were divergent on the matter of the relationship between the full-time job and the second job. How should the second job's income be treated? And how should the engineers and technical personnel act? Whether the Sunday Engineers' behavior was legal became a controversial question at that time. Unfortunately, some Sunday Engineers were even convicted of taking bribes.

The divergence was clearly exposed in the Han Kun case (Wang and Liu 2010; Qian and Zhu 2009). Han Kun was a research assistant of Shanghai Research Institute of Rubber Products in 1979. At the same time, he and several colleagues were employed by a rural rubber products manufacturing factory as technical advisers. With the approval of the Research Institute, they came to the rubber products factory every Sunday. Ten months later, they successfully improved the production process, which earned the factory more than 400,000 Chinese dollars. The factory rewarded Han Kun's group 3400 Chinese dollars, of which 1200 were given to Han himself. A year later, the local People's Procuratorate sued Han Kun to the local Court for committing bribery. After 3 month's investigation, Du Jingfeng, a judge of the local Court, believed that there was a lack of evidence and this required supplementary investigation. The local People's Procuratorate sued Han again on March 1, 1982. Then, the President of the local Court asked for advice from the Legislative Affairs Office and Science and Technology Cadre Office of Shanghai Municipal People's Government. They all agreed with the local Court that Han should not be sentenced, and the policy on incomes and rewards for professional advice by scientific and technological personnel given to other enterprises and institutes was discussed.

Those positive responses from the higher authorities worked up to a point. Han was immune from prosecution. But he was still punished through his labor in a boiler room since the first prosecution. When Xie Jun, who was a journalist of Shanghai office of *Guang ming ri bao* (Guangming Daily), one of the important Chinese-language daily newspaper in China, accidentally learned of Han's experiences, he wrote an article titled "Being Praised for Saving a Factory, and Innocent of Accepting the Rewards" on the front page of *Guang ming ri bao* on December 23, 1982. This newspaper published some letters from readers with different opinions afterwards.

These discussions promptly attracted the attention of the central government. The Central Political and Legal Affairs Commission of the CPC held a special meeting to discuss the Han Kun case on January 21, 1983. A significant decision had been made: Han's case cannot constitute a crime; and others who were put in jail due to similar charges should be released; prosecutions of similar cases would not be allowed by public security departments; the central government would propose a separate study on the policy of incomes and rewards for part-time jobs. Two months later, the Scientific and Technological Cadres Bureau of the State Council published "The Interim Regulations on Scientific and Technological Personnel's Part-time Employment". The State Science and Technology Commission issued "The Opinions on Several Problems in Scientific and Technological Personnel's Part-time Employment" on November 18, 1988.

With the government's approval and encouragement, more and more engineers became Sunday Engineers. The Shanghai Association for Science and Technology set up the Federation of Sunday Engineers in May 1988 in order to build a bridge for the technology transfer and communication between the township enterprises and Shanghai technological personnel. More than 2000 engineers joined the federation on its establishment day. It is said that almost 20,000 Shanghai Sunday Engineers were employed by the township enterprises in 1988 (Wu and Li 1988).

During the long 1980s, the reform of the system for science and technology was constantly deepened. As a special kind of engineer, the Sunday Engineers phenomenon became a symbol of the reform of the science and technology system in China. It undoubtedly was a unique sight in the long 1980s as large numbers of Sunday Engineers marched to the countryside every Saturday and returned to the urban areas on Monday. As a special group formed in this period of transformation from the planned economic system to the market economic system, the phenomenon of Sunday Engineers obviously reflected the effect of the social environment on engineers, which should be recorded in the history of modern engineers in China.

9.5 Conclusion

Entrepreneurs and engineers are not only important social roles, but they are also key members of the engineering community. When China introduced its planned economic system, and was dominated by the appropriate ideology from the 1950s to 1970s, entrepreneurs disappeared and engineers were seriously restricted. These led to an abnormal structure for the Chinese engineering community, i.e. an engineering community with no entrepreneurs and bound engineers. During the reform in the long 1980s, entrepreneurs reemerged and engineers were gradually emancipated. To make a long story short, the structure and function of the engineering community have been influenced by technological development, by both the economic system and the ideological system, and by social tradition. In this context, a good understanding of engineering practice and the engineering community can only be achieved when they are understood within the context of the close connection and mutual interaction among engineering, economy, ideology, and society.

References

Beder, S. (1998). *The new engineer: Management and professional responsibility in a changing world*. South Yarra: MacMillan Education Australia.

Bergere, M. C. (2008). The Chinese bourgeoisie, 1911–1937. In J. K. Fairbank (Ed.), *The Cambridge history of China*, *Republican China, 1912–1949, Part. 1* (Vol. 12). Cambridge: Cambridge University Press.

Brewer, A. (1992). *Richard Cantillon: Pioneer of economic theory*. London: Routledge.

Carvalho, L. C. (2015). *Handbook of research on internationalization of entrepreneurial innovation in the global economy*. Hershey: IGI Global.

Chen, D. (2008). Gai ge kai fang 30 nian zhong guo qi ye jia qun ti de cheng zhang he ming yun [The growth and destiny of Chinese entrepreneur group in the 30 years of reform and opening up]. *Economic Affairs*, (3), 34–36.

Guanzi. (2001). *Guanzi* (trans: Rickett, W.A.). Princeton: Princeton University Press.

Jin, G. (2012). *Zhong guo gao deng gong cheng jiao yu fa zhan yan jiu* [Research on the development of higher engineering education in China]. Beijing: Beijing Institute of Technology Press.

Johnston, V. R. (2000). *Entrepreneurial management and public policy*. New York: Nova Science Publishers.

Li, B. (2010). *Gong cheng she hui xue dao lun: gong cheng gong tong ti yanjiu [An introduction to engineering sociology: On the engineering community]*. Hangzhou: Zhejiang University Press.

Liu, G., & Dong, Z. (1999). Xin zhong guo 50 nian suo you zhi jie gou de bian qian [The changes of the ownership structure in 50 years of New China]. *Contemporary China History Studies, Z1*, 26–38.

Qian, H., & Zhu, D. (2009). Han Kun wu zui, di er zhi ye cong ci he fa hua [Han Kun is innocent, and hence the second-job employment is legalized]. *Government Legality*, (5), 48–49.

Rui, L. (2006). Su nan xing qi ri gong cheng shi xian xiang ji qishi [The inspiration of sunday engineers in South of Jiangsu province]. *Red Flag Manuscript*, (18), 36–38.

Wallerstein, I. (1979). *The capitalist world-economy*. Cambridge, UK: Cambridge University Press.

Wang, L., & Liu, M. (2010). Xing qi tian gong cheng shi: yi ge te shu qun ti de dansheng [Sunday engineers: The birth of a special group]. *Sino-Foreign Digest*, (5), 36–38.

Wu, X. (2012). *Die dang yi bai nian: zhong guo qi ye 1870–1977 [One hundred years of twists and turns: Chinese enterprises 1870–1977]*. Beijing: Zhong xin Press.

Wu, M., & Li, Z. (1988). Shanghai xing qi ri gong cheng shi you xi lu [The records of Shanghai Sunday Engineers' worries and happiness]. *Outlook Weekly*. April 6, 28–30.

Zhu, W. (2004). *Qi ye jia ben wei lun: zhong xiao qi ye suo you quan zhi du an pai yan jiu [Enterprise-oriented theory: On the institutional arrangement of small- and medium-sized enterprises' ownership]*. Beijing: Economic Science Press.

Zhu, M., Cai, J., & Avery, M. (Eds.). (2009). *China's emerging financial markets: Challenges and global impact*. Singapore: Wiley.

Nan Wang MA in the Philosophy of Science and Technology at the Dalian University of Technology. PhD in Philosophy of Science and Technology at the Graduate University of Chinese Academy of Sciences. Associate professor at University of Chinese Academy of Sciences. Her recent English publications are: "Philosophical perspectives on technology in Chinese Society", *Technology in Society*, vol 35 (3), 2013; "The Emergency of Chinese Discussions of Engineering, Philosophy and Ethics", *Technology in Society*, vol. November 43, 2015 (also the Guest Editor). Her research areas include: philosophy of technology, philosophy of engineering, and engineering sociology.

Bocong Li MA in Philosophy. Professor in Philosophy at University of Chinese Academy of Sciences, Vice-Director of Research Center for Engineering and Society of UCAS and Editor-in-Chief of *Journal of Engineering Studies.* He has published several books, including 工程哲学引论 *An Introduction to Philosophy of Engineering* (2002), 选择与建构 *Selection and Construction* (2008), 工程社会学导论 *An Introduction to Sociology of Engineering* (co-author, 2010), 工程哲学 Philosophy of Engineering (co-author, 2007, 2013), *Theory of Engineering Evolution* (co-author, 2011) and *Engineering, Development and Philosophy: American, Chinese and European Perspectives* (co-editor, Springer 2012). Research areas: philosophy of engineering, philosophy of science, sociology of engineering, history of engineering.

Chapter 10
Industry and the Development of a New System of Higher Technological Education in the UK 1955–1965: A Shared Responsibility?

John Heywood

Abstract There is a continuing conflict between education and industry that begins with the different perceptions that educators and industrialists have of the purposes of tertiary education through to university study. For example at the present time there is a pressure from industry on the higher education sector to prepare new graduates immediately for work. In so doing industry places the responsibility for education and training on the institutions of higher education and through their fees on the students for their education and training. The purpose of this chapter is to examine the extent to which responsibility was shared between the colleges and industry when England and Wales had a national system of higher technological education and training based on the sandwich principle in the 1950s and 1960s, and to show that industrialists working with educationalists are capable of producing innovatory curricula. Harold Silver the Historian of the Council for National Academic Awards 1964–1989 (*A Higher Education (1990) London, Falmer*) reports that of the thesis and dissertation literature for the earlier period, that is the period too which this chapter relates there were only two that were relevant, one of which was the authors (p 279). Such research as there was is documented in Heywood, J. and R. Ann Abel (1964) *Technical Education and Training in the United Kingdom. Research in Progress 1962–1964*. Slough. The National Foundation for Educational Research). If engineering education is to progress practitioners in both academia and industry will require an understanding of the substantial knowledge base that has been developed, which implies some kind of training. Only in this way will they learn to share responsibility at the operational and executive levels of curriculum delivery and planning.

Keywords Academia · Accreditation · Assessment · Competence · Curriculum innovation · Industry · Industrial training · NCTA · Percy committee · Policy · Problem/project based learning · Responsibility · Sandwich (cooperative) courses · Technological education

J. Heywood (✉)
Trinity College Dublin, Dublin, Ireland

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_10

10.1 Introduction

At the present time there are pressures from industry on the higher education sector to prepare new graduates immediately for work. In so doing industry places the responsibility for education and training on the institutions of higher education and through their fees on the students for their education and training. Some large organizations are seeking to bypass universities altogether by providing their own training systems. However, research suggests that it is not possible to "completely" train a graduate for immediate use in industry. Blandin (2011) and Sandberg (2000) have shown that competency is context dependent. The knowledge, skills, and procedures that comprise a competence are affected by the context and indicators of competence. Blandin (2011) found that the cognitive dimension of competence had five main competency indicators. One "acting as an engineer in an organization" was found to be more important than the others and was thus the core competency. It is difficult to see how such a composite can be learnt in a traditional college course unless steps are taken to cater for this need (Korte 2009). Even then it can only be preparation for internalization and can only occur with experience. Blandin concludes that there are four main steps in the development of competence that "appear" to be driven by the core competence. It drives the socialization/insertion process within the company. It also triggers then fosters the development of managerial competency (mobilizing human resources appropriate for action (e.g. Humble cited in Heywood 1970)). It makes the development of the other competencies necessary. It also maintains students' motivation for learning, at least for learning what they feel useful at the moment to solve the problems posed by acting in professional settings. It is clearly a developmental process that continues after the student has left college. Universities and industry have neglected the developmental needs of students in spite of the substantial research of such investigators as Perry (1970), King and Kitchener (1994), and Torbert (1987) in the realm of professional behavior (Heywood 2016).

In so far as Blandin's enquiry was concerned the core competence "develops only within the company and cannot exist without long experience within a company." Within the company, the students developed competencies that were specific to their job. It has to be objected that very often long experience is no longer available for many jobs are no longer permanent and life-long. Nevertheless there are generic competencies applicable to any job that have to be developed in situ, as for example, Trevelyan's (2010) competence in "technical liaison." Components of that competence such as communication may be developed in college, if appropriately done (Trevelyan 2014).

The writer takes from these studies that interaction between periods of academic study and industrial work as found in sandwich (cooperative) courses should help students to acquire professional competence in engineering that is not available to courses of the traditional kind that have no organized industrial contact. For their success such courses will have a shared responsibility for the development of the student which means closer liaison than in the past, and those responsible for running them will not be able to ignore the extensive educational knowledge base that has emerged in the last 50 years (e.g. Heywood 2005; Johri and Olds 2014).

The purpose of this chapter is to examine the extent to which responsibility was shared between the colleges and industry when England and Wales had a national system of higher technological education and training based on the sandwich principle in the 1950s and 1960s, and to show that industrialists working with educationalists are capable of producing innovatory curricula.

10.2 Historical

The system of further education in England and Wales can be dated to 1882 when the Regent Street Polytechnic (now Westminster University) was founded (Cotgrove 1958). Other Polytechnics were soon founded and by 1910 they had nearly a 1000 university students studying for degrees of the University of London. Prior to that, the Institution of Civil Engineers had introduced its own examinations in 1870.

In 1921, immediately after the end of the Great War the Institutions of Electrical and Mechanical Engineers agreed to participate in a scheme of National Certificate Examinations administered by the Ministry of Education. They were set at Ordinary and Higher levels and attained after continuous part-time study, 3 years in the case of the Ordinary Certificate, and two more years in the case of the Higher Certificate. These examinations were used to gain exemption from the examinations of the professional institutions although additional subjects called "endorsements" had to be taken to gain full exemption. A full time course of 3 years was available in some colleges and students who successfully completed the course were awarded a Higher National Diploma. The associate membership of these institutions designated by A.M (e.g. A.M.I.Mech.E) demonstrated that the holder had either completed a university degree or one of these equivalent qualifications which were held to be at the level of a pass or ordinary degree. In 1957 more engineers obtained professional membership of the 13 recognized institutions from the alternative route than from the universities (Payne 1960). Figure 10.1 presents a simplified picture of the system as it was in 1957, the beginning of the period under discussion in this chapter. It will be seen that the technical college sector provided a route to higher qualifications for students in secondary modern schools who had to leave them at age 15 when compulsory schooling ended. But so did the technical and grammar schools for those who chose to leave at 16. Since many of these students came from skilled and unskilled working class families the alternative route provided for mobility subject to aptitude and interest. Part-time study in the technical colleges played a major role in the education of engineers but there was a clear division of labor. The technical colleges provided academic study and industry provided training. While the academic qualifications provided a suitable measure of academic study there was no supervision or regulation of the training received in industry. There was no overall oversight of courses or regulation. Responsibility was not shared. Neither was there any legal obligation on firms to provide education and training.

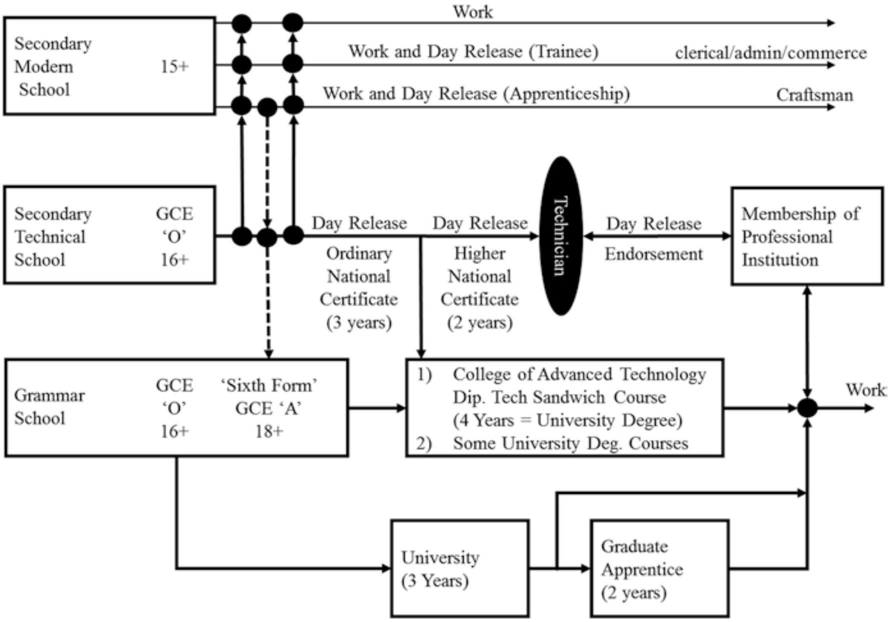

Fig. 10.1 Very simplified model of the system of further and higher technological education in England and Wales Circa 1956. Supported by a system of regional (technologist/technician courses), area (technician courses), and local (craft, trade, operative courses) technical colleges

In 1944 a Committee on Higher Technological Education was established by the Government to consider the education and training needs of the workforce. The Committee chaired by Lord Eustace Percy came from the educational élite and focused on the need to increase the qualified technological workforce.

In its report (MoE 1945) the committee began by categorizing the types of technologist that industry required, a task that would inevitably mean that it would have to consider the roles of the universities and technical colleges in meeting the needs when defined. The five categories were:

1. Senior administrators.
2. Engineer scientists and development engineers.
3. Engineer managers (design, manufacture, operation and sales)
4. Technical assistants and designer draughtsmen
5. Draughtsmen, foremen and craftsmen.

The committee felt that group 5 fell outside its remit. Of group 4 they wrote that they were "outside the limits we have set ourselves with this report." It is of interest to note that although the report uses the term "technological" in its title it refers to engineers in categories 2 and 3. Cotgrove (1958) argued that it began a focus on qualified manpower that was at the expense of technicians.

The committee accepted figures for the annual output of engineers given to them by the professional institutions, and argued that an output of 3000 should be maintained for at least 10 years. These would be in the traditional forms of engineering, that is, civil, electrical and mechanical. Subjects like production and control engineering were not considered part of undergraduate studies. The technical colleges would have to provide upwards of 1500 and many of these would have to be for category 3 after allowance had been made for the expansion of university departments. The committee also forecast the need for courses in industrial administration.

The war had left the nation with a situation that required an "energetic expansion, both in accommodation and staff, which will tax to the full the resources of universities and technical colleges, coupled with adequate arrangements for keeping a close watch on the demand which this program is intended to meet." These proposals were supported by the Barlow Committee in 1946 when it reviewed the Nation's manpower needs (Barlow 1946).

10.3 Percy Committee and the Need for Different Styles of Education and Training

The operational philosophy of the Percy Committee was that "every technology is both a science and an art. In its aspect as a science it is concerned with general principles which are valid for every application; in its aspect as an art it is concerned with the special application of general principles to particular problems of production and utilization." From which they concluded that because the "art" aspects were necessarily learnt in formal works training and the "science" aspects in academic study, technical colleges had in the past selected and emphasized the "art" aspect. This led them to the view that that the different styles of training in the universities and technical colleges would lead to engineers with different qualities.

The committee attempted to justify its thinking on educational grounds based on the view that universities train for manpower group 2, technical colleges and universities train for group 3, while group 1 obtains its supply from persons trained in all sectors.

The committee recognized the explosion of knowledge that had taken place during the war and took the view that all engineers trained by university or technical college require "a much longer course of combined academic study and works practice extending over at least five or six years," for neither the university nor the technical college is designed "alone to produce a trained engineer." While they persisted with the differentiation between the art and the science of technology they considered that the main defect of technical college education was the evening structure that gave "too small a space to the fundamental sciences in the early stages." The report foreshadowed the trend toward day release and subsequently to full-time study, and began the trend toward courses based on engineering science in the technical colleges.

Of the 1500 engineers to be trained by the technical colleges the Percy Committee thought that 1000 should be trained via the Higher National Certificate route. But 500 or so should have a course of higher technological education that required continuous full-time study over substantial periods. They did not specify a particular structure although it is clear that the period of academic study should be no less than that for a university degree in aggregate interwoven with planned courses of works practice. They suggested that the period of academic study might be between 24 and 30 weeks per annum.

One hundred fifty of 500 students who should receive higher technological training would do so by means of external degrees although the committee thought these were an anomaly. "University degrees should not be granted purely on examinations, or in respect of courses conducted solely in the evening or on the basis of part-time day release. We recognized however, that there may be justifiable exceptions to this general rule." For the remaining 350 students they desired

> to see courses specifically planned without reference to existing anomalies. We would insist that such courses, whatever their length and arrangement, should be directed to the development to the highest level of teaching of the art of technology based on sufficient scientific foundation. Such courses should have a status in no way inferior to the university courses, they should require equal ability in the student; and they should afford preparation for the most advanced post-graduate studies […] what is chiefly required of technical colleges is adaptability to changing techniques and new combinations of techniques. This consideration applies with even greater force to other less well established technologies, in which it is essential that institutions responsible for teaching should be free to develop new standards by experiment. Such freedom implies not only freedom to plan their own syllabuses, but freedom also to award their own qualifications. This freedom of a teaching community to adapt its examinations to its teaching is now the characteristic mark of institutions to which is to be entrusted the development of a type of higher technological education which is, for the most part, new to this country. (MoE 1945, p 11)

So the committee recommended that six colleges exclusive of the Greater London area be created to develop "technological courses of a standard comparable with that of university degree courses." These colleges should be relieved of elementary teaching duties (i.e. manpower levels 4 and 5). The committee debated long and hard about what the qualification to be awarded by these colleges should be called. They firmly rejected the idea that it should be a degree. "The objection to the degree is twofold. It would not receive the support of the universities and would not provide technological education with its own hall-mark." So the equation *diploma = degree*, was born, together with the principle that these technological institutions should produce engineers of a different quality to those of the universities.

It took 10 years for politicians to create a system that was similar to that proposed by the Percy Committee.

10.4 The National Council for Technological Awards

In 1955 the government created the National Council for Technological Awards (NCTA). Its purpose would be to make awards to successful students of technology from technical colleges and help those colleges develop, and maintain high standards of technological education. The Council was to be chaired by Lord Hives who was also chairman of Rolls Royce. The Council created the award of diploma in technology (dip.tech) to equate with that of a university degree. Entry to the new diplomas was the same as for universities with the exception that holders of 'good' national certificates were also eligible.

Whereas the Percy Committee's recommendations had been made in respect of engineering and engineers the NCTA was given a brief that would allow it to offer diploma's in the traditional sciences as applied and mathematics. But there its remit ended. It was not allowed to offer awards in the humanities and social sciences. The purpose was to produce scientists motivated to apply their knowledge to the solution of industry's problems. Therefore, all the diploma programs were required to be sandwich (co-operative) courses. But there was no requirement that they should all have the same structure. There were many variants, the most common of which was the 6 month in industry/6 month in college by 4 year program, commonly known as a "thin" sandwich course. There was a "thick" variant that required the students to do 1 year in industry prior to 2 years in college, which were to be followed by another year in industry and a final year in college. The structure of sandwich courses caused difficulties for some industrialists (see below).

In the following year in a White paper the government reorganized the technical education sector into four tiers (MoE 1956). At the base would be Local Technical Colleges and newer Colleges of Further Education. They would offer course up to the level of the Ordinary National Certificate (ONC). There were approximately 300 colleges in this category. Another 200 or so Area colleges were also to teach up to the level of the ONC but some would be allowed to do more advanced work. Of the order of 30 or so Regional Colleges would retain low level work but primarily undertake advanced level work in their region. At the apex were to be Colleges of Advanced Technology (CATs) whose name is self-explanatory. Eight such colleges were named in the White paper. The intention was to develop the CATs in order that they would ultimately enjoy a status comparable with that of a university. Nevertheless, the government of the day confirmed its intention of creating a dual system of education at the highest level and this remained in place until 1992. However, the operational philosophy was one of expansion and not difference. There was, inevitably, competition between these colleges and the universities for resources (Heywood 1969). The reorganization of the technical education sector was completed and a ninth CAT was added to that group in 1962.

The White paper defined the terms technologist and technician taking its definitions from EUSEC which it subsequently used in the 1959 Crowther report (MoE 1959) on the education of the 15–18 year old population, and a White paper "Better Opportunities in Technical Education" published in 1961 (MoE 1961). They originated with the Conference of Engineering Societies of Western Europe and the United States of America (EUSEC) in 1953 as definitions of professional engineers and technicians and are shown in Tables 10.1 and 10.2 (EUSEC 1961). The Americans did not adopt these definitions (JEE 1964). While official and

Table 10.1 The definition of technologist used in the 1956 White paper

"The Technologist is competent by virtue of his fundamental education and training to apply scientific method to the analysis and solution of technological problems. He should be capable of closely and continuously following progress in his branch of engineering science by consulting and assimilating newly published information and applying it independently. He should thus be able to make contributions on his own account to the advancement of technology. His work is predominantly intellectual and varied, requires the exercise of original thought and judgment, and involves both personal responsibility for design, research, development, construction, etc., and also supervision of the technical and administrative work of others."

Table 10.2 The definition of a technician used in the 1956 White paper

"The technician is one who is qualified by specialist technical education and practical training to apply in a responsible manner proven techniques which are commonly understood by those who are expert in a branch of engineering, or new techniques prescribed by a professional technologist. His work involves the supervision of skilled craftsmen and his education and training must be such that he can understand the reasons for and the purpose of the operations for which he is responsible. Not all industries acknowledge technicians as such. The job, however described, may involve: the design of plant and equipment under the direction of a technologist; supervising the erection and construction and maintenance of plant; testing and surveying; inspection etc".

professional circles accepted these terms some industrialists did not (Beaver 1920). They did not want their hands to be tied in how they employed engineers. The White paper foreshadowed the stratification of courses into discretely organized channels that became a reality in 1972. In a word, persons pursuing Higher National Certificate courses would be deemed to be on a technician route. However, in 1956 they continued to follow that route to professional recognition. By incorporating the technologist definition in the White paper the government was clearly indicating that those educated to become technologists in the technical education sector would be employable in the Percy Committee's category 2. Although this point does not seem to have been picked up in the literature it has considerable implications for the curriculum. It should be noted that in this definition and the earlier forecasts of the Percy and Barlow (1946) committees it was not thought that women would become engineers.

There are three features of these proposals on which this discussion should focus. These are:

1. The sandwich (cooperative) principle.
2. The Diploma would be equivalent to a university degree.
3. Colleges other than the CATs would be allowed to offer courses for the dip. tech.

The implications of the first were that the program could not function without the support of industry, and this raises the issue of responsibility. The implication of the third was that from the beginning the CATs were not unique because other institutions could offer the qualification for which the CATs were created.

10.4.1 The Sandwich (Cooperative) Principle

Sandwich courses however organized require the support of industry for industrial training places. In most cases that support went beyond the provision of training places and extended to the support of students. In most cases students obtained a place within a company that arranged an academic place for them subject to their having the appropriate entry qualifications. These "industry-based" students had their fees paid for by the company and they received remuneration for their work. "College-based" students had their fees paid by their Local Education Authority and may or not have received re-numeration from their employer during their industrial periods. Much smaller in number they studied mainly in the science areas of the curriculum. Employers also sponsored students at universities on 1-3-1 courses. On leaving school the student entered university for a year and re-joined the company for a further years training when they had completed their degree course. Some employers offered 2 years post graduate training. Thus apart from the day release National Certificate route there were a number of pathways for students to prepare for industry and pursue the practical components necessary for membership of a professional institution. Of these the most costly for the employer were the dip.tech programs. In 1961 these cost £2000 (app $5600) compared with £1400 (app $2000) for a 1-3-1 course (Heywood 1969). It was therefore a major decision for an employer to sponsor a dip.tech student, but it was related to the employer's needs for qualified employees. Fortunately employers valued integrated training because they believed that it made a person more immediately useful. They also believed that because of their education many undergraduates were unsuited to industry (Bosworth 1963). Finally, they believed that work experience would help the students develop qualities that could not be developed by the educational process (Heywood 1969; Marris 1964).

10.5 Practical Industrial Support for the Diploma in Technology

The proportion of firms in the UK providing effective training was small. For undergraduates the firms with attractive training schemes tended to be in the medium to large category. Bearing in mind that firms had a range of options open to them it is perhaps not surprising that relatively few organizations supported the dip.tech. When the diploma program ended in 1964, 456 organizations were supporting dip. tech training. The smaller firms that supported training seemed to have a high ratio of qualified staff.

By the closure of the NCTA 2250 students had graduated in engineering subjects of which 1682 were in electrical and mechanical engineering which suggests that the diploma program was meeting the Percy Committees demand for an output of

500 graduates per annum. In applied science (applied or industrial chemistry) 308 had graduated, and 297 had graduated in applied physics.

But the successful launch of the Diploma program depended in no small measure on the electrical and electronic engineering industry. Of the first thousand diplomats over 30% were sponsored by firms in this sector. One firm alone GEC accounted for 20% of the output. The English Electric company accounted for 6%, and AEI 5%. Other firms in the industry contributed but with relatively small numbers compared with these three very large organizations. Without their support dip.tech student numbers would not have risen at anything like the rate that actually occurred.

10.6 Operational Responsibility

Operational responsibility relates to the actual responsibilities for the delivery of the academic curriculum on the one hand, and on the other hand, the provision of industrial training. That is with the college's teachers and the organization's industrial trainers who worked with the students on a day-to-day basis. By and large the institutions left each other to their own spheres of competence. They cooperated rather than taking a joint responsibility for the program as a whole. Some industrialists would have liked to have made suggestions about the syllabus but in general the teachers were wary of such interventions. College tutors visited students during their industrial periods but there was a wide variation in practice and a lack of clarity about their purpose (Rice 1965) as there was about those who supervised industrial training in detail (Jahoda 1963, see below).

In 1962 an officer of the NCTA said that very little had been done to evaluate whether industrial training was playing its part in the educational process. The professional institutions played an important role in determining the quality of industrial training through their regulations, but their assessment of training and their evaluations of experience were subjective (Heywood 1969, p. 545). Nevertheless they did help maintain standards. The NCTA would have liked to assess (accredit) training schemes in the same way that they approved courses but because of the large number of firms involved found the task impossible. However, Birmingham CAT awarded an Industrial Training Certificate that required a similar but shortened process to the NCTA's for a diploma program.[…]

> each participating firm is required to submit its scheme (or schemes) of training for approval by the Committee. The procedure for doing this is given together with a broad outline of the industrial training required as an integral part of the course leading to the dip.tech (eng). After each training period a report is required from the firm on the nature of the training received by the student and his performance. The College arranges for a member of staff to visit the student at his work at appropriate intervals throughout his periods of training, usually twice within each period. On completion of the final period all documents relating to the student's training are submitted to the committee for final assessment and certification. Certification of each student's actual training is a condition of the award of the Diploma, and this together with his final examination results is considered by the NCTA for the conferment of the Dip.Tech. (Heywood 1969, p 548)

The term "assessment" implies "evaluation" rather than the direct assessment of a student's learning.

Brunel CAT probably did more than any other CAT to develop procedures for assessment and instigated research into the assessment of industrial training. "The panel is joined from time to time by representatives of firms and these joint discussions have resulted in steady improvement of the level of training, the ironing out of difficulties and in increasing efficiency" (Skellon 1959). A large number of students and diplomats thought industrial training should be assessed. Some years' later rubrics began to be used in the assessment of industrial training (Ford and Rennie 1999; Rakowski 1990). It seemed that each side took its own responsibilities very seriously. Whereas there was cooperation there was no co-responsibility. The same could be said of executive responsibility – the level of policy making.

10.7 Executive Responsibility

Executive responsibility is exercised at the level of policy and relates in particular to the regulations set by the NCTA and the possibility of influencing what happens in the curriculum. The approval of courses was undertaken propter hoc. Because the following are found to be in place the course will be of the required standard. (Details of the syllabuses (lists of content), information about tuition hours per subject, timing of the subjects in the course, qualification details of the staff who would teach on the program and detailed information about the resources that would support them had to be given in the application for recognition of a course). The panels were made up of experts from both academia (more often than not the universities) and industry. The extent to which courses could be innovatory was determined by these panels.

The only judgement made of the success of a program or otherwise was that of the external assessors. The examination papers and assessment procedures would be approved by an external examiner who would also validate the marks by inspection of the candidates' scripts. The external examiners (more often than not university professors) had to be approved by the NCTA. A program would be approved for 5 years. It was up to the external examiners to ensure that it met the required standard, that is, parity with the equivalent programs offered by universities (Heywood 1969).

10.8 The Beginning of the Divide

It was evident that while each side took responsibility for their work and while there had to be collaboration responsibility was not shared. This became evident when it came to be believed that while there was some innovation in the curriculum the evidence pointed to a general "curriculum drift" toward mirroring university courses

(Heywood 1969). Given the number of teachers who had experience of or who were currently teaching at this level in the Colleges this was not perhaps surprising. It was also clearly a function of the search by many in the CATs for university status.

It caused some industrialists to complain that the CAT courses were no longer doing the tasks for which they had been established. Their complaint was not heard neither was their complaint about the structure of sandwich courses. Since there was no co-responsibility for the development of programs there was no real exchange of thought. The electrical industry who were the plaintiff responded by creating an organization to represent them – The Electrical and Electronic Manufacturers Joint Education Board (EEMJEB) to represent them at the policy (political) level. Secondly, the Personnel Director of the English Electric Company (G. S. Bosworth) was able to intervene in the debate, as will be explained. EEMJEB were particularly concerned with the structure of sandwich courses.

10.9 The Electrical and Electronic Manufacturers Joint Education Board (EEMJEB)

In their 1961 annual report they criticized colleges running dip.tech courses for not introducing end-on structures.

> The growth of sandwich courses in the past few years has produced certain problems in the training field. In most companies it has resulted in overloading of their training facilities for half the year and a relatively slack period for the rest of the year. The busy period also coincides with the university long vacation and makes it increasingly difficult for those companies who are engaged in running sandwich courses to take vacation students from the universities and colleges. One way of avoiding this overloading for the half year would be for a far wider adoption of end-on sandwich courses, which would improve training facilities by increasing capacity and effectiveness. Each college would run two courses per annum, commencing in September and February, instead of one course beginning in October or September as at present. The Board felt that the position was so serious that representations should be made to the Ministry Education without delay. (Heywood 1969, pp. 515–517)

This they did, and the result was that a sub-committee of the National Advisory Council on Education for Industry and Commerce was established to investigate the problem. Its chairman was Sir Lionel Russell Chief Education Officer of Birmingham. E. R. L. Lewis who was Controller of Education of the English Electric Co. was invited to represent the Board on this sub-committee. The Board was also supported in its stance by the London and the Home Counties Regional Advisory Council for Technological Education.

EEMJEB also complained about the syllabuses that were offered.

> In the early days when the proposals for the award of a Diploma in Technology were discussed the electrical and electronic engineering industry were under the impression that the courses leading to the award would be modelled more clearly on the needs of industry than on courses leading to a university degree. The new award for the Diploma in Technology (Eng) was therefore welcomed as being complementary to the university degree by meeting

> more fully the growing variety of needs in the profession and industry. The industry is however disappointed at the general tendency for Diploma in Technology courses to follow the lines of conventional university courses rather than to strike out on new and complementary lines that were envisaged to meet modern industrial requirements. These to include the need for technologists trained and qualified to undertake projects of conception, design, manufacture and operation that will be such as to put British industry in the lead and to build up trade against increasing technological and economic competition in all parts of the world. The Joint Board considers that the question of the nature of the Diploma in Technology courses in electrical and electronic engineering is of both importance to national prosperity and it is therefore advocating that steps should be taken to bring the courses progressively in line with modern trends of industrial needs. (cited in Heywood 1969, pp. 517–518)

There was evidence that supported EEMJEB's view. First, the external examiners of the dip.tech who were often university professors were of the opinion that universities and the CATs were moving in the same direction. But they attributed considerable value to industrial experience. They reported little difference between dip.tech examinations and those set in universities. Second both in terms of student expectations and work actually done as graduates the distinction made by the Percy Committee was that universities should be the primary trainers of R&D personnel and that dip.tech students were expected to go into R&D and especially Engineering Management. Among the diplomats from whom data was obtained in one study 38% were in research suggesting that their courses had not prevented them from a getting a research post. As for their future careers the diplomats in this sample looked toward having increased responsibility for the work they did (Heywood 1969: see also Heward et al. 1968).

10.10 The Problem of Design

The second largest area in which diplomats were employed (19% of the sample interviewed) was design including the designing of systems. Otherwise none of the other areas of industrial activity exceeded 7%. At the time design was considered to be a problem and the government had commissioned a committee chaired by G. B. R. Feilden to report on "Engineering design" (Feilden 1963). Among the recommendations of the Committee was that candidates for membership of the Institution of Mechanical Engineers should require experience of design. Further the Engineering Institutions Joint Council should include a new category of membership to include technicians and draughtsmen. Support for teaching of design was to come from a study of the attitudes to their education of mechanical engineers by Hutton and Gerstl in 1964. Their ideal university course would include a 19% allowance for design engineering and specialty education. Their proposals were very similar to the proposals made by the Grinter Committee in the United States to the American Society for Engineering Education in 1955 in which 25% for the area of design was suggested.

A major problem was that only rarely did universities show any interest in design. It was not a respectable subject, and in any case it was debatable as to whether it could be taught. The situation was not dissimilar in the United States. This complaint could not be made against many dip.tech courses. It was argued that project work in these programs helped students understand design processes. Pullman (1964) argued that because of the industrial experience obtained in sandwich courses students could undertake ambitious projects. His paper is of added interest because it described project work at Rugby College of Technology, a college that was dependent for many of its students on Rugby's two major employers', Associated Electrical Industries and English Electric.

Perhaps the biggest problem was that the term "design" was used in a variety of ways by industry. For many the stereotype was of a designer draughtsman and as Monk showed engineers did see time in the drawing office as contributing to their careers (Monk and Heywood 1977). Lord Hives, the chairman of Rolls Royce said, "The usual university graduate does not take kindly to drawing office work." he went on to say, "industry is largely responsible; there is not sufficient encouragement to create first-class designers." He linked the problem to the value attached to applied science by society at large. In his definition, the designer is a member of the team of production engineers. He saw a unity of design, development, and production that could not be shown in an organizational chart. But Bosworth (1963) in a striking paper on creativity in engineering in 1963 wrote that "the increasing complexity and division of industry has now not only separated design from manufacture but has sub-divided the design process itself into stages."

Commenting on the Hutton and Gerstl study a senior industrialist told this writer that while the report was of interest "it will bring us no nearer to solving our cardinal problem which is to establish a dip.tech syllabus which will best suit the holder of the dip.tech to do the things industry will require of him" (Heywood 1969).

Nevertheless it is difficult to find very detailed comments among the responses to questionnaires and the literature except those of Bosworth. The complaint that dip.tech graduates would not be able to "undertake projects of conception, design, manufacture and operations" leads to the question why were they not put on such projects during the industrial period, and what was wrong with the substantial projects the students undertook in college in their final year? No detailed investigation of curriculum was undertaken and neither was there any formal investigation in to what students learnt in the extensive projects they did from this perspective? And where were the jobs that required these skills and why was there no detailed discussion with the colleges about them and their requirements. Answers to these questions suggest a lack of responsibility by both partners and only limited collaboration, a fact which if correct leads to other questions.

For example, why were these industrialists not able to influence the college advisory boards of governors on which they sat? Why were colleges organized such that industrialists might have a more direct influence on their work? Part of the problem was that there was a tradition that the work of the colleges should be left to the colleges and the work of industry to industry. Another component was the fear of academic staff that what industry wanted was training. A contributory factor was that there was not a common technical vocabulary available to them for discussion of curriculum issues. For example, at that time Tyler's principles of curriculum had not become part of educational thinking in the UK. The "Bloom Taxonomy" was unknown in the UK. Moreover there was no forum for the discussion of the higher education curriculum per se. The same problem persists to this day in spite of the strong knowledge base in engineering education that has emerged. Academics and those responsible for training in industry need to acquire the common technical language that this has provided if the divide is to be abolished.

But taking all the evidence together there was little to suggest that overall industry was generally dissatisfied with dip.tech syllabuses. Nevertheless, in addition to the Russell Committee that investigated the structure of sandwich courses the Government appointed another committee to look more generally at the education and training requirements for the electrical and mechanical manufacturing industries. It was chaired by G. S. Bosworth.

10.11 The Bosworth Committee

It appears that Bosworth gave up his attempts to influence the undergraduate curriculum for the committee did not regard the training of product technologists as a matter of curriculum orientation or syllabus content. It said that the "emphasis given to the principles of engineering science is, in our view correct since it is on these foundations that technological advance is based." The committee proposed a "matching section" within an industrial context as a means of induction to manufacturing. The report adopted the principle that individuals should be developed in parts. The theoretical part first, the practical second. The committee assumed that basic education did not over-orient the student to the analytic approach and thus to an interest in research. It further assumed that basic education had little effect on overall motivation and that students entering courses for an industrial career would remain motivated to this end. There was also the assumption that teaching methods could not be changed to help develop the attitudes of mind required of the young engineer in industry. These assumptions are highly questionable and there were some criticisms of them at the time. Although the recommendations led to suggestions for the development of post-graduate training the committee recognized that some of their proposals were relevant to undergraduate education and training.

> The view was strongly presented by young graduates particularly that several elements of training we proposed could with advantage replace less relevant material in undergraduate courses. Manufacturing engineering was instanced, and we believe there should be further enquiry into the means of providing an element of practical content with manufacturing engineering in or before the full-time degree course. (cited by Heywood 1969, p. 440)

There were courses that did just this. Although Bosworth by 1966 seems to have given up trying to influence undergraduate programs, a report published in the same year as his proposed an alternative curriculum that had its origins in his thinking

(Heywood et al. 1966). The group who wrote this report comprised three educationalists and four industrialists. Of these five had a direct association with the English Electric Company and two had had a connection with its subsidiary the Marconi Company one in a senior position. All members of the group had had some association with industrial training.

10.12 An Alternative Curriculum

When Charles Carter (later Sir Charles) Vice-Chancellor (President) of the new University of Lancaster sought permission to develop an engineering department from the University Grants Committee, its representative Sir Willis Jackson (later Lord) a distinguished engineer made it clear to the university that proposals for departments in the traditional engineering subjects would not be accepted. This served to confirm what Carter had been told by industrialists including Bosworth. Carter was no stranger either to industry or engineering. As an economist he had been the joint author of a major report on industry, in addition to which his father a Fellow of the Royal Society was Director of Research of the British Thompson Houston Company (merged to form AEI) based in Rugby. He was open to new ideas and asked his senior research fellow in higher education (this writer) to bring together the aforementioned group to make proposals for an alternative curriculum. They prepared what the journal "Engineering" called a "voluminous report" on the education of professional mechanical engineers for design and manufacture (145 pages[1]). The title was somewhat misleading because the model presented worked from a broad base toward a specialism which could equally have been electronic or electrical engineering.

The model was based on the 1-3-1 sandwich principle. The 1st year would be in industry and carefully designed in the manner that the Bosworth Committee envisaged. The 2nd year (or first academic year) did not follow the normal pattern. Its aims were cited as,

> to make an alternative approach to the teaching of engineering science called "engineering analysis". To reinforce the experience of the first year. This is achieved partly in "engineering analysis" and partly in "engineering synthesis" […] which is an attempt to introduce students to all aspects of design, e.g. the customer, quality control, working in teams, ethics etc. (Heywood et al. 1966, p. 102)

The intention was that this should be achieved by an extensive project accompanied by a lecture program that while having some independent progression, was allied to the project and its progress. Social science aspects were intended to be integral to this course. Finally there would be an extension of mathematics as a tool for solving problems.

[1] An electronic version of the report is available from the author.

It was the idea of "engineering analysis" that is of interest here for it turned the traditional epistemology of the curriculum on its head. It originated with Bosworth and a colleague of his Barry T. Turner who was also a member of the group that produced the report. In the model which has been briefly described elsewhere (Heywood 2005):

> the activities of engineering are related to the sources of engineering when, for this purpose, engineering is defined as the practice of the art and science of making things. Thus the object is created from sources in people, who use energy, forces, materials, space and themselves for its invention, and who in doing so ask a number of questions about its activity and the activities of the sources, location and acquisition etc. The teaching begins in the concrete and moves to the abstract, from the known and tangible to the unknown and intangible.

The purpose was to develop an "attitude of mind toward scientific problem solving in the industrial environment.

The authors believed that the total engineering need had to be considered and they thought this would be achieved through "the subject of design via the known and familiar, motivation becomes high and interest is at once around" […]. Later, they argued that "the student is concerned with the theory of the design procedure, and thus the methodology of manufacture. The student is shown how to look at the system (a) so as to formulate the problem, and (b) to obtain optimized general solution. In considering the system, he breaks it up into sub-systems and components; he comprehends how sub-systems can be standardized, and learns how to use them as building blocks, since new design is often modification of an old one"[…]. The authors intended that a problem solving approach would be used that was based on a carefully chosen set of exercises (mini-projects). Today it would be called problem-based learning (PBL). They also insisted in the jargon of today that the program was an integrated study and not an interdisciplinary study in the first 2 years.

They were clear that the "overall aim was to develop a philosophy of engineering, which includes an understanding of the need to work in teams. Students are asked to look at problems outside the normal limits of engineering" […] They argued that some part of the induction course should be devoted to the philosophy of engineering.[2]

10.13 Conclusion

In no way could this curriculum be considered to be training yet it originated with the ideas of an industrialist. It was developed by a group of educators and industrialists who set out quite clearly their intention to state a philosophy of engineering

[2] The Vice-Chancellor distilled this report into a four page document in which he proposed that the university create an engineering department to offer such a curriculum. Senate rejected the document wanting a more traditional approach. Subsequently the Vice-Chancellor wrote another proposal that resulted in the founding of a department of engineering. The person appointed to the chair was an engineering designer from Cambridge University. The university does not have a copy of the first document but has retained a copy of the second.

education, and in so doing gave attention to relevant educational thinking which is set out clearly in the report. Much of what was discussed continues to be discussed today. Change the examples and no one would find it surprising.

It is a poor reflection on the part of policy makers in education and industry that so much of what they say is based on opinion and ignores the extensive knowledge base that has been erected. If engineering education is to progress practitioners in both academia and industry will require an understanding of this base, which suggests some kind of training. Only in this way will they learn to share responsibility at the operational and executive levels of curriculum delivery and planning.

Acknowledgement This chapter is a development of two papers published by the author at the 2011 and 2014 annual conferences of the American Society for Engineering Education (Heywood 2011, 2014). I thank the Society for permission to reprint extracts from these papers.

References

Barlow. (1946). Scientific manpower. Report of a Committee appointed by the Lord President of the Council.Cmd 6824. London, HMSO. The Barlow Report.

Beaver, H. (1920). Engineering and civilisation. 6th Graham Clark Lecture. *Journal of the Institution of Electrical Engineers, 6*. 205 ff.

Blandin, B. (2011). The competence of an engineer and how it is built through an apprenticeship program: A tentative model. *International Journal of Engineering Education, 28*(1), 57–71.

Bosworth, G. S. (1963). Towards creative activity in engineering. *Universities Quarterly, 17*, 286.

Bosworth, G. S. (1966). *The education and training requirements for the electrical and mechanical manufacturing industries committee on manpower resources for science and technology*. London: HMSO.

Cotgrove, S. (1958). *Technical education and social change*. London: Allen and Unwin.

EUSEC. (1961). *Report on education and training of professional engineers* (Vol. 1). London: Institution of Electrical Engineers.

Feilden, G. B. R. (1963). *Engineering design*. London: HMSO.

Ford, N. J., & Rennie, D. M. (1999). Development of an authentic assessment scheme for the professional placement period of a sandwich course. In J. Heywood, J. M. Sharp, & M. Hides (Eds.), *Improving teaching in higher education*. Salford: University of Salford teaching and learning Qualkity Improvement scheme.

Grinter, L. (1955). Final report on the evaluation of engineering education. *Journal of Engineering Education, 46*(1), 25.

Heward, C., Mash, V., & Heywood, J. (1968). Student reaction to sandwich courses for the Diploma in Technology (Dip.Tech). *Bulletin of Mechanical Engineering Education, 7*, 253.

Heywood, J. (1969). An evaluation of certain post-war developments in higher education. Thesis. Lancaster, University of Lancaster.

Heywood, J. (1970). Qualities and their assessment in the education of technologists. *International Bulletin of Mechanical Engineering Education, 9*, 15–29.

Heywood, J. (2005). *Engineering education. Research and development in curriculum and instruction*. Hoboken: NJ IEEE/Wiley Interscience.

Heywood, J. (2011). *Higher technological education in England and Wales between 1955 and 1966. The contribution of the British electrical engineering industry*. Proceedings Annual Conference of the American Society for Engineering Education. Ac 2011-634.

Heywood, J. (2014). *Higher technological education and British policy making: A lost opportunity for curriculum change*. Proceedings Annual Conference of the American Society for Engineering Education. Paper 8689.

Heywood, J. (2016). More by luck than good judgement: Moral purpose in engineering education policy making for change (pp. 1–6). ASEE/IEEE Proceedings Frontiers in Education Conference. https://doi.org/10.1109/FIE.2016.7757552.

Heywood, J., Lee, L. S., Monk, J. D., Moon, J., Rowley, B. G. H., Turner, B. T., & Vogler, J. (1966). The education of professional engineers for design and manufacture (a model curriculum). *Lancaster Studies in Higher Education, 1*, 2–151.

Hutton, S. P., & Gerstl, J. E. (1964). *Engineering education and careers*. Proceedings of the Institution of Mechanical Engineers. 178, Part 3F Proceedings of a symposium on education and careers.

Jahoda, M. (1963). *The education of technologists*. London: Tavistock.

JEE. (1964). *Journal of Engineering Education, 54*, ix.

Johri, A., & Olds, B. M. (2014). *Cambridge handbook of engineering education research*. New York: Cambridge University Press.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment*. San Francisco: Jossey Bass.

Korte, R. F. (2009). How newcomers learn the social norms of an organization: A case study of the socialization of newly hired engineers. *Human Resource Development Quarterly, 20*(3), 285–306.

Marris, P. (1964). *The experience of higher education*. London: Routledge and Kegan Paul.

MoE. (1945). *Higher technological education*, *The Percy Report*. London: HMSO.

MoE. (1956). *Technical education* (1956), *Whitepaper. Cmnd 9703*. London: HMSO.

MoE. (1959). *Report of the central advisory council for education*, *Crowther Report* (pp. 15–18). London: HMSO.

MoE. (1961). *Better opportunities in technical education*, *White paper. Cmnd 1524*. London: HMSO.

Monk, J. D., & Heywood, J. (1977). The education and career patterns of professional mechanical engineers in design and manufacture. *The Vocational Aspect of Education, 29*(72), 5–16.

Payne, G. L. (1960). *Britain's scientific and technological manpower*. Stanford: Stanford University Press jointly with Oxford U.P in the UK.

Perry, W. B. (1970). *Forms of intellectual and ethical development in the college years*. New York: Holt, Reinhart and Winston.

Pullman, W. A. (1964). Teaching design to sandwich courses students. *Proceedings of the Institution of Mechanical Engineers, 179*(1), 100–112.

Rakowski, R. T. (1990). Assessment of student performance during industrial training. *International Journal of Technology and Design Education, 1*(20), 106–110.

Rice, R. (1965). A survey of the industrial work period of students of the diploma in technology at a college of advanced technology. *The Vocational Aspect of Education, 17*, 15.

Sandberg, J. (2000). Understanding human competence at work. An interpretive approach. *Academy of Management Journal, 43*(3), 9–25.

Skellon, J. H. (1959). Planning of the industrial training period. *Journal of the Royal Institute of Chemistry*. https://doi.org/10.1039/519598300202.

Torbert, W. R. (1987). *Managing the corporate dream*. Homewood: Dow-Jones Irwin.

Trevelyan. (2010). Restructuring engineering from practice. *Engineering Studies, 2*(3), 175–195.

Trevelyan, J. (2014). *The making of an expert engineer*. London: Taylor and Francis Group.

John Heywood He holds a higher doctorate from Trinity College. He is a Life Fellow of the American Society for Engineering Education, and the Institute of Electrical and Electronic Engineers, and an Honorary Fellow of the Institution of Engineers Ireland. His research interests are in engineering education, its philosophy, curriculum and instruction. He came to Trinity College Dublin, where he was Professor of Teacher Education, from the Faculty of Engineering of Liverpool University where he lectured in industrial studies and management. Prior to that he conducted research at Lancaster University into examinations and assessment, and designed new

models of assessment for engineering science in schools. In the 1970s he directed the first major study of engineers at work for the purpose of determining objectives for training technologists and technicians. His 2005 award winning book, *Engineering Education. Research and Development in Curriculum and Instruction* is one of the ikons of the multi-million dollar development of engineering education as field of scientific inquiry in the United States. He has over 100 publications and his most recent book *The Assessment of Learning in Engineering Education. Practice and Policy* was published earlier this year. An additional book *The Human Side of Engineering*" is in the press.

Chapter 11
The Expanding Business of the Entrepreneurial University: Job Creation

Mike Murphy and Michael Dyrenfurth

Abstract This chapter explores the role of universities in job creation. It does this by taking two approaches. The first is to look at how the university sees its role as expanding from traditional first and second mission activities to encompass third mission activities including industry engagement, and how this supports job creation and economic development. The second approach is to examine how new jobs are created in a geographic region or country, and the role that the university can play in support of this. Typical third mission activities such as incubators, technology transfer, and science parks are also examined; including the role of government support and incentives.

Keywords Job creation · Role of the university · Third mission · Policy · FDI · SME · Innovation · STEM · Economic development

> You can guarantee lifetime employability by training people, making them adaptable, making them mobile to go other places to do other things. But you can't guarantee lifetime employment. – Jack Welch (2001)

This chapter evolved from material originally presented at the ASEE 2012 Annual Conference and published in: Murphy, M, & Dyrenfurth, M. J. (2012, June), *Examining the Role of the University in Creating Jobs.* Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://peer.asee.org/21357

M. Murphy (✉)
Academic Affairs, Digital & Learning Transformation, Dublin Institute of Technology, Dublin 2, Ireland
e-mail: mike.murphy@dit.ie

M. Dyrenfurth
Technology Leadership and Innovation Department, Purdue Polytechnic Institute, Purdue University, West Lafayette, IN, USA
e-mail: mdyrenfu@purdue.edu

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_11

11.1 Introduction

There is little argument about the value of higher education and its contributions to society. For example, James Duderstadt has written that the contemporary research university reaches into every aspect of modern society:

> It educates the graduates that sustain commerce, government, and professional practice; it performs the research and scholarship so essential to a knowledge-driven global economy; and it applies this knowledge to meet a diverse array of social needs including health care, economic development, and national security. (Duderstadt 2004)

Typically universities view their mission in terms of three streams of activity: teaching and learning; research, often termed discovery; and service, now more recently termed engagement. Depending on the kind of university an institution is, and on the tenor of the time and the economic environment and context in which it is operating, the relative importance of each of these three missions can vary. For many institutions on both sides of the Atlantic, the importance of the third mission, i.e. engagement, has increased in importance relative to the first and second mission. We also observe that the relative emphasis is not a 'zero sum' game, but rather that the role of the university continues to expand to encompass more responsibilities than ever before.

The authors, coming from Ireland and the United States, focus this chapter on the dimensions of the university that contribute directly or indirectly to job creation as the outputs of the three missions of the modern, entrepreneurial university. We do this for two reasons. First, in both the United States and Ireland, even though both seem to have put the economic recession of 2008 behind them, job creation and economic development remain critically important to ensuring and maintaining societal living standards into the future. Therefore it is appropriate to ask the question of organisations receiving public monies as to what role they can and should play in advancing the economies of the societies housing and supporting them. Second, universities today generally accept their role as being wider than teaching and research, and so engage in a range of engagement activities—the latter is particularly true of US land grant universities and other institutions with similar missions.

Much has been written of the necessity and benefits of university third mission activities with respect to economic development, but less has been written with respect to a key output of university activity, namely job creation. Therefore, this chapter looks for evidence of sustainable job creation resulting from the activities of universities. Given the rhetoric focused on jobs, and its link to a nation's sense of its well-being, it is more than prudent for university leaders to consider their institution's role in job creation. In particular, university faculty and administrators dealing with science, technology, engineering, and mathematics (STEM) programs must consider how they and their activities make and can make contributions to this critical imperative. By doing so, they perhaps can develop "a better understanding of the conditions under which technological innovation can be made to function more effectively in the generation of economic growth" (Landau and Rosenberg 1986, p. v–vi).

Thus we examine the role of the university in job creation, including through its first and second missions of learning and discovery, analyse the literature addressing university job creation, present findings and draw conclusions.

11.2 The (Expanding) Role of the (Entrepreneurial) University

Today it is generally accepted that the core functions of the entrepreneurial university are knowledge distribution (via learning), knowledge generation (via research), and knowledge transfer (via engagement with stakeholders outside of the university). These are described respectively as first, second and third mission activities of the university. University involvement in each of these core functions developed historically. André Oosterlinck described this development as follows:

> The oldest function of a university, dating back to the Middle Ages, is knowledge distribution. This is what universities have done for many centuries, without bothering too much about knowledge creation. Only towards the end of the 18th and the beginning of the 19th centuries, did universities feel the need to contribute to knowledge progress, and to actively create new knowledge. ... The third essential activity, apart from knowledge distribution and knowledge creation, is still younger. We have to wait till the second half of the 20th century to witness the birth of what is called knowledge transfer to society at large. This meant that universities started to realize that they are not located in an isolated ivory tower, but that they have responsibilities to fulfil which go beyond knowledge creation and knowledge distribution, not only among our students, but in society at large, which should benefit from the very existence of universities. (Oosterlinck 2004, p. 121)

Figure 11.1 graphically shows the historical development of these missions, with societal triggers and prototype or frontrunner institutions (adapted from Trencher et al. 2014).

Universities can be viewed passively as facilitators or actively as engines of economic development. In either case, there is generally no confusion regarding their

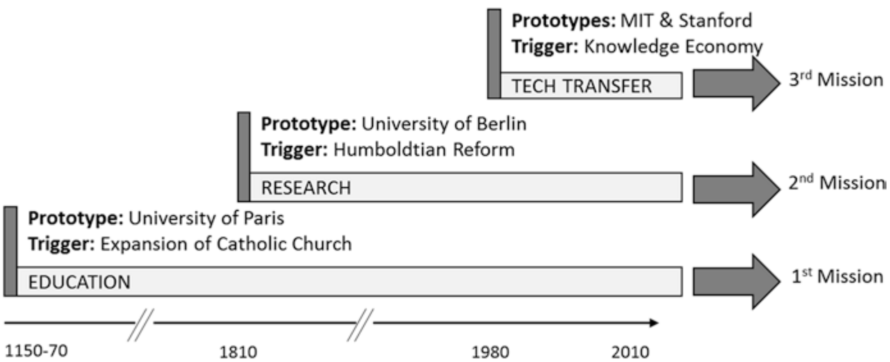

Fig. 11.1 Emergence of university missions with triggers and prototypes

first and second mission activities. Perhaps the Kellogg Commission (1999) report entitled *Returning to our roots: The engaged institution* broached this topic most cogently during the early days of its ascendency. However, the emergent description of a third mission can be ambiguous, and at its simplest refers to the range of university activities not covered by the first or second mission. Third mission activities can be diverse and span a wide spectrum, and can be grouped into three distinct sets of activities: (a) Technology Transfer & Innovation activities; (b) Continuing Education activities, and (c) Social Engagement activities (E3M 2011). The activities within the grouping of Technology Transfer & Innovation are those most directly associated with economic development and include such elements as intellectual property licensing, technology parks, support for spin-out companies, external consultancy, technology problem solving, etc.

Generally, third mission technology transfer and innovation activities are driven by economic objectives. Economic value and value for money are becoming more important for universities as performance indicators. We will return to aspects of third mission activities later in the chapter to examine the evidence in the literature of their effectiveness. Individual universities with distinct mission statements will balance all three core activities (learning, discovery, and engagement) in pursuit of their specific mission, but modern universities generally pursue all three functions in order to justify the name "university". These core functions contribute individually and collectively to the well-being of society, but to differing degrees. Each of these missions will be explored with regard to its role and effectiveness in creating jobs.

11.3 Jobs-Oriented Perspective of Universities

Specifically with respect to creating jobs, we first take a different perspective – i.e., one that might be considered retrospective – on the role of the university in creating jobs. We look at job creation simply from the perspective of mechanisms to create the largest number of jobs, rather than accept that the third mission activities of universities, in and of themselves, are the best or indeed the only mechanisms by which universities create jobs. We argue that if the regional or national goal is job growth, then the focus must be on how and where the greatest job growth occurs.

11.3.1 Attracting Large Companies into the Region

Considering a country like Ireland, or a region such as the State of Indiana, in the United States, what is the best mechanism to create jobs, and hence economic stability or indeed prosperity, within that geographic area? We argue that the single most effective way to quickly grow jobs within these areas is to attract large companies into the regional or national geographic footprint. "In today's knowledge economy, universities are recognized increasingly not only as centers of learning but also as focal points of regional growth and employment" (Wessner 2011). So, for example, within Ireland consistent government strategy since the 1960s has been to attract foreign direct investment (FDI) into Ireland and the FDI sector has been an important contributor to Ireland's economic performance over this period. Successfully convincing one large company to re-locate into the region or country, to build a new plant or facility there, will likely add thousands of new jobs that are directly employed by the new company, and in addition thousands of additional secondary jobs that emerge to support the company because it happens to now be located in that region.

In Ireland, the government agency tasked with increasing FDI is IDA Ireland, and according to IDA Ireland (2015), the impact that FDI has made to the Irish economy is highly significant, being responsible for employing 174,448 directly, and supporting an estimated 122,000 indirect jobs. With a workforce in Ireland of almost two million people, this means that approximately 15% of the total workforce is either employed directly by FDI companies or employed in support companies. Similarly, an example from the State of Indiana documents that the Subaru automobile assembly plant in Lafayette Indiana, which began producing cars in 1989, now directly employs over 4600 people (Wikipedia 2017).

Companies, often multinationals, choose to relocate into one region rather than another for a range of reasons, such as access to new markets, suitable employment law, and a favourable tax environment. One additional and often very important reason is the size, quality and educational preparedness of the workforce in that region. Government agencies can leverage the quality of the educational system as they work to entice companies to relocate into their geographic footprint. According to the Irish National Strategy for Higher Education to 2030, the "expansion of higher education opportunities has been critical in generating the supply of skilled graduates that underpinned the significant increases in productivity, employment and export oriented roles achieved from the mid-1990s to the early years of the current century" (Higher Education Authority 2011, p. 31). When prospective companies visit a country or region in which they are considering establishing a new plant or facility, the relevant government agency will invariably bring the executives on a "roadshow" to visit local universities and technical institutes to demonstrate the quality of the talent pool available. The quality of third level education is particularly relevant for advanced manufacturing, information, and services jobs. Figure 11.2 is a snapshot example of the type of extensive information by which IDA Ireland promotes Ireland as a destination country based on the quality of its education system (IDA Ireland 2016).

It is also worth noting that when a country or region pursues FDI as a strategic objective, then this in turn can impact on the focus and support of its third level education system. So, for example, IDA Ireland in referring to government support states that the Irish "Government's technology skills action plan aims to make Ireland a global leader for technology talent and skills. The target is to meet 74% of forecast industry demand for high-level technology skills from the education system by 2018, up from the current level, estimated at over 60%" (IDA 2015). The result is greater support for STEM education and training, including re-skilling pro-

Fig. 11.2 Talent and education in Ireland

grams. In fact, in Ireland, the third level non-university sector significantly expanded between 1970 and 2000 directly in response to, and in support of, the government's initiative to attract multinational companies into Ireland as a manufacturing base.

Attracting a large company to relocate into region is a major achievement. However products and services have a normal life cycle and it is not unusual to see multinational companies consider relocating their plants and facilities again near the end of that life cycle. Therefore maintaining the company in a region often requires additional support and other forms of engagement, including expertise, within that region. One such mechanism is the support that universities can provide through research, often targeted use-inspired research, which companies can access in order to extend the life cycles of products and services, or indeed to create new products and services. For example in Ireland consider the Tyndall National Institute, which is closely aligned with University College Cork, and is a "national and global leader in impact from ICT research excellence". According to its chairman Eoin O'Driscoll, during 2015 "Tyndall continued to work closely with industry in these areas to enhance product and service offerings by delivering on its mission of creating impact through scientific excellence. Tyndall's contribution to Ireland's long-term competitiveness lies in its focus on market-ready research and its relationship with industry" (Tyndall 2015).

Taking a US example of FDI, one of the prime university tools for job creation has been the Technology/Research/Science Park. In reporting on a US National Research Council symposium on research parks, Wessner (2011) added the concept of regional innovation clusters to the mix of such entities:

> Responding to the challenges of fostering regional growth and employment in an increasingly competitive global economy, many U.S. states and regions have developed programs to attract and grow companies as well as attract the talent and resources necessary to develop innovation clusters. These state and regionally based initiatives have a broad range of goals and increasingly include significant resources, often with a sectoral focus and often in partnership with foundations and universities. These are being joined by recent initiatives to coordinate and concentrate investments from a variety of federal agencies that provide significant resources to develop regional centers of innovation, business incubators, and

> other strategies to encourage entrepreneurship and high-tech development. This has led to renewed interest in understanding the nature of innovation clusters and public policies associated with successful cluster development (p. xiii).

Therefore to have the largest impact on the creation of new jobs, we argue that the quality of the third level educational system is essential, and therefore the university, through discharging its traditional first mission role of learning is fundamentally important to job creation. To quote Gerhard Casper in speaking about the origins and success of Stanford, he said that "the story of Stanford (and therefore ultimately that of the relationship between Stanford and the Silicon Valley) is not a story of a university that set out to become a locomotive of economic change in its region and country. Rather it is the story of a university that, especially in the period following World War II, built on and increased its commitment to the highest-quality teaching and research, and the pursuit of innovation" (Casper 1998).

11.3.2 Job Creation in Small and Medium Companies

Moving beyond use of foreign direct investment as the primary mechanism to create large numbers of jobs, the next area to focus on should be support for the small and medium enterprise (SME) sector of the economy. According to industry experts, fast-growing small businesses are the engine of jobs growth in the global economy (Dell 2011). "Small firms account for a disproportionately large fraction of job creation and destruction relative to their share of employment. Jobs created by small firms are no less likely to persist than those created by large firms" (Hijzen et al. 2010, p. 621).

Typical definitions of small companies are those which employ fewer than 50 employees, with annual turnover of less than €10 million. A medium-sized company employs between 50 and 249 employees, with an annual turnover of less than €50 million (Enterprise Ireland 2017). Regarding the location of most job creation, in 2011 the OECD reported:

> SMEs (small and medium-sized enterprises) account for 60 to 70 per cent of jobs in most OECD countries, with a particularly large share in Italy and Japan, and a relatively smaller share in the United States. Throughout they also account for a disproportionately large share of new jobs, especially in those countries which have displayed a strong employment record, including the United States and the Netherlands. (OECD 2011, p.3)

From a job creation perspective, the role of the university should be to help the small or medium sized company to scale up. This can be achieved through consultancy, process improvement and support for new product or service ideation and development. Research collaboration between companies and universities will often be supported in one manner or another by the state, for example through research tax credits or intellectual property (IP) policy support. An existing company, be it small or medium, has the infrastructure to support its expansion, which is generally not the case with a start-up company. The development or extension of a new product or service, for example through new functionality or adjacent markets, will likely result in the growth of new jobs. Also, it is easier for a smaller company to grow by 10–20% in this manner; thereby a multitude of new jobs can be created through at least some support from the local university. For example, in Ireland, the government agency Enterprise Ireland provides a number of supports for established companies. These supports include: a graduate program that matches graduates with companies to develop and execute plans to grow in key markets; an Innovation Vouchers program, each voucher worth €5000, which are available to assist a company to work with a university or knowledge provider to explore a business opportunity or technical problem; support for collaborative research projects with research partners across Europe; SME-customised management education, to enable senior managers to learn and apply best management practice to support their global growth; and a job expansion fund to support new employment (Enterprise Ireland 2017). In the USA, taking Purdue University's TAP (Technical Assistance Program) as just one example, we noted that the *2014–2015 Annual Report* (2015) listed their program's Indiana impact as: "456 Jobs created/saved…Economic impact of increased sales $24.8 million…Retained sales $116.8 million…Cost savings $9.3 million…Capital investment $24.2 million…Reaching 625 employers in 71 counties" (p. 2).

Examining the supports that small and medium sized companies would benefit from in order to expand, it is clear that the role of the university is to (1) be sufficiently close to industry as to have expertise that can support companies in their near term goals, and (2) produce the type of graduates who will perform well in companies seeking to expand. In both cases this requires the university to focus on the quality of its educational programs and also to maintain close connections with its key industry sectors, perhaps through collaborative research. Therefore, as we argued above with regard to FDI, the traditional university first mission role of learning combined with the third mission role of industry engagement are important to job creation in the SME sector.

Another key role of the university, which again works at the intersection of first and third mission activities, is workforce development. In analysing knowledge-based industries and the successful North Carolina model, Nichola Lowe has documented the critically important combination of university educational roles with targeted and customized workforce development. She has observed that universities can act as workforce intermediaries that expand local employment opportunities. "Vocational training supports play a crucial role in the upgrading process by enabling firms to enhance and expand worker skill" (Lowe 2007).

We note that many universities see training as outside of their mission, and not encompassed within their first mission of teaching and learning. However, in a German study, the underlying value of workforce development was found to be considerable. "According to recent research, the reform of an education system providing adequate skills for all citizens could increase GDP by much as 10% in the long term" (Bertelsmann Foundation 2009).

11.3.3 Start-Up Companies

In continuing our jobs-oriented perspective of the university, let us now turn our attention to start-up companies. In this regard, universities generally adopt a range of reasonably well-understood mechanisms, under the umbrella title of university third mission, or industry engagement. These include incubator support, licensing support, technology transfer, and research/science/technology parks on or adjacent to the university campus. Incubator support is typically oriented around a program to help people to take a concept or an idea and to successfully launch their business. "Job creation is a main underlying purpose of incubator support for new business formation, especially of technology-based firms. Incubators can also play an important role in … regional economic development" (OECD 1997). These supports include mentoring, workshops, and ecosystem of like-minded entrepreneurs, access to investors and funding, etcetera.

In a more recent paper Tamásy (2007), described the prevalence of parks and incubators, but felt compelled to conclude that in general they were less successful than their aspirations would suggest:

> Today, technology-oriented business incubators are a worldwide phenomenon, although empirical research evidence clearly suggests that they tend to fail in supporting entrepreneurship, innovation, and regional development and, therefore, do not fulfil their expected role as policy instrument. … Finally, the business incubator idea in practice is actually a very modest contributor to regional economic development. Using the logic of the NBIA [National Business Incubator Association], creating on average 20,000 jobs per year in a nation with a [US] labour force of 147.4 million and an unemployed rate of 5.5 percent (in 2004) is not really a big push. (p. 460)

An example perhaps of where universities can have too great an expectation of their ability to create jobs from their third mission activity came from the announcement of a university research alliance established in Ireland between University College Dublin (UCD) and Trinity College Dublin (TCD). In 2009, as Ireland inexorably slid into a terrible financial depression, the Irish Prime Minister announced that the two universities were to establish a research alliance with the goal of creating 30,000 jobs in the 4-mile corridor between the two campus locations. The alliance was to be supported by €650 million drawn from state, and industry funding. It planned to bring together PhD education, research and enterprise for job creation, and was to be modelled on Silicon Valley and Boston, which were anchored on the research-intensive universities of Stanford and MIT, respectively. It also looked at the success of Nokia in Finland as a goal to develop a leading home-grown technology company in Ireland. The alliance would build on the two universities' existing technology transfer operations and enterprise facilities. A task force was established to develop the policy, legal and infrastructural elements that would be required to facilitate such world-class innovation. From the perspective of the universities, they saw it as a visionary job creation plan, which was part of the national recovery initiative as Ireland headed deeper into financial crisis (Flynn 2009). While the alliance was well-intentioned and politically supported, it was ultimately not successful, and certainly not from the perspective of its goal to create 30,000 jobs. However, individually both universities continue to successfully pursue their research agendas as two of Ireland's leading research universities.

11.4 A University-Oriented Perspective on Jobs

In this section we take a university-oriented perspective to examine how the university sees itself creating jobs both directly and indirectly. This should be contrasted with the previous section which looked at activities the authors believe create the most jobs. Whereas here we will examine (i) the value of higher education to the graduate; (ii) the university as a direct employer of large numbers of people; and the economic value of the university to the region in which it is located; (iii) the economic/jobs argument for research in universities; and finally (iv) we will describe in some detail the third mission activities adopted by innovative and entrepreneurial universities, particularly those that result, or are intended to result, in job creation.

Job creation by universities occurs by means of at least three streams as depicted in Fig. 11.3 and as described below:

1. The actual employment of people by universities as they increase their size, service reach, and intensity of effort in each of their three missions
2. The job creation that comes from university sparked entrepreneurship activity, start-ups, incubators, technology and research parks (third mission)
3. The additional recruitment undertaken by business, industry, social service agencies, and government as they expand their functions to better meet needs, and to take advantage of new capabilities that research and development due to university second mission outcomes engenders.

These three streams are conceptually illustrated in Fig. 11.3. The dashed lines indicate that while the exact shape or proportions of two of the three contributors to

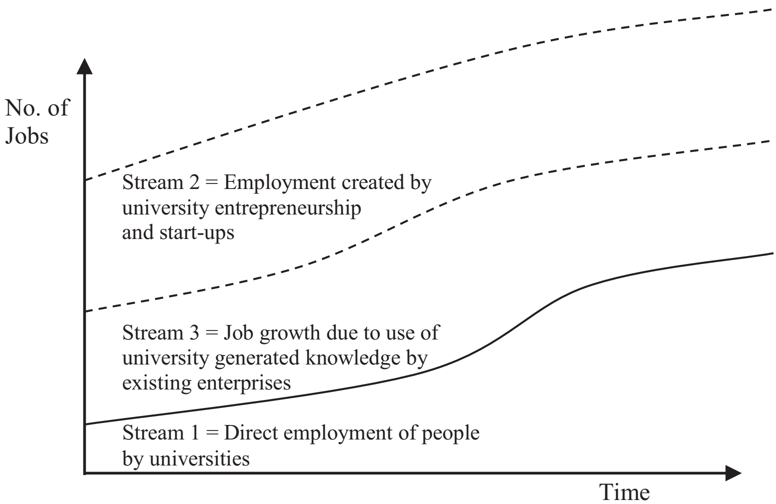

Fig. 11.3 Conceptual view of University involvement in job creation

job creation by universities is unknown, while the data for university staff employment is relatively well known as indicated by the solid line.

11.4.1 The Value of Higher Education to the Graduate

Let us first of all establish the fact that higher education is of direct financial value to the individual who pursues a third level qualification. Because the individual has acquired that third level qualification he or she is more likely to have a job which pays better than someone without qualification. Therefore there is a win-win situation for the individual in terms of their job and career prospects, and the company in terms of acquiring necessary advanced skills to support the company's goals. As a consequence, Claudia Goldin and Lawrence Katz have written that "higher education in the United States expanded at extraordinary rates during most of the twentieth century. Whereas 10 percent of all Americans born in 1900 attended some college 50 percent of those born in 1950 did" (2008 p. 283). Goldin and Katz present data that show education as still a very good investment. "In fact, the marginal individual today who does not graduate high school, who does not continue to college, and who does not complete college, is leaving large amounts of money lying on the street" (*ibid*. p. 325). Figure 11.4 below (adapted from Fig. 8.1 of Goldin and Katz, p. 290), shows that there is a wage premium for both high school graduates and college graduates, but that the college wage premium has increased significantly from 1950 (with the exception of the 1970s), and that this wage premium continues to widen for college graduates.

While Fig. 11.4 shows a wage premium for both college and high school graduates in the Unites States, Steven Rattner (2017) presents US Bureau of Labor Statistics evidence that further underscores the value of a college education. Figure 11.5 shows the percentage change in inflation-adjusted weekly pay from 1979 to 2016 for US workers.

Goldin and Katz sound a warning when they write that "college is no longer the automatic ticket to success. Rather, degrees in particular fields and advanced training in certain areas are now exceedingly important. … No longer does having a high school or college degree make you indispensable, especially if your skills can be imported or emulated by a computer program". (*ibid*. p. 353).

According to Thomas Piketty, "in the long run, the best way to reduce inequalities with respect to labor as well as to increase the average productivity of the labor force and the overall growth of the economy is surely to invest in education" (Piketty 2014, pp. 306–307). He argues that over the long run education and technology are the decisive determinants of wage levels. Interestingly, Piketty also examines whether educational institutions foster social mobility. He makes the point that qualification levels have shifted upwards: "a high school diploma now represents what a grade school certificate used to mean, a college degree what a high school diploma used to stand for, and so on. As technologies and workplace needs changed, all wage levels increased at similar rates, so that inequality did not change"(*ibid*. p. 484).

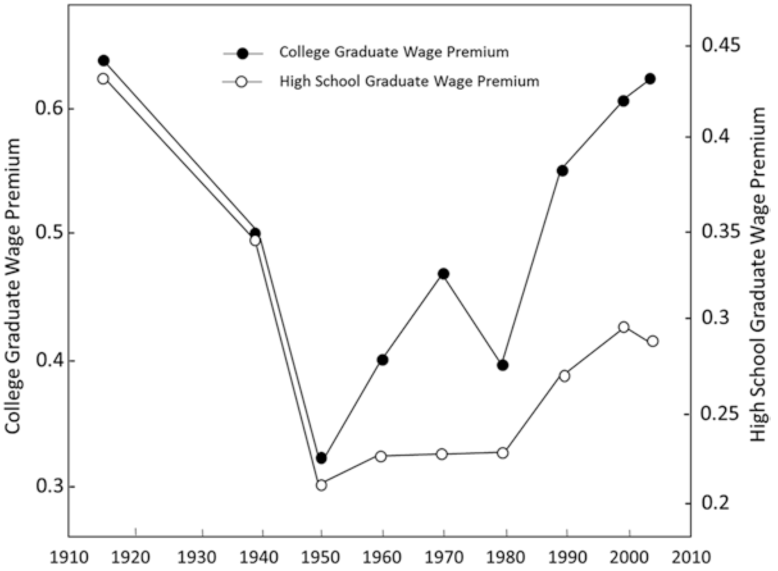

Fig. 11.4 College graduate and high school graduate wage premiums

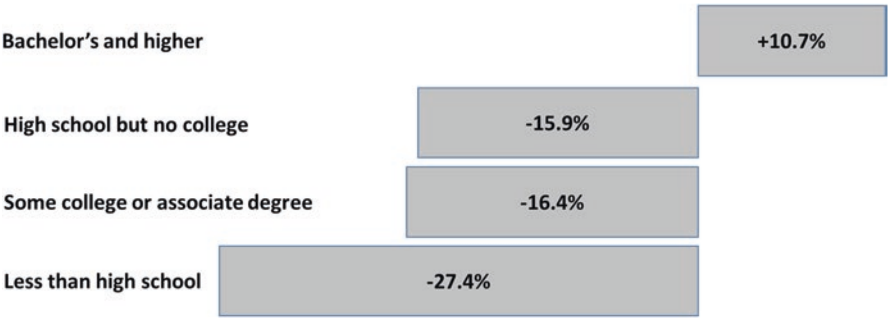

Fig. 11.5 Percentage change in inflation-adjusted weekly pay – 1979–2016

11.4.2 Universities as Employers

Third level education is big business. In the United States approximately 2.6% of the gross domestic product (GDP) of $18 trillion is expended on third level education, with 1.6% on private institutions and 1% on public institutions. In Ireland, €2.3 billion representing approximately 1.25% of GDP is spent on third level education with the majority of that amount spent on public education. The percentage of students attending higher education has increased significantly. Table 11.1 shows the increases in the percentage of population holding a tertiary qualification (adapted from Table A1.3 in OECD 2016).

Table 11.1 Percentage of population holding a tertiary qualification

	25–64 year-olds	
	2005	2015
Ireland	29%	43%
USA	39%	45%
OECD average	27%	35%
EU22 average	24%	32%

Table 11.2 Full-time-equivalent staff in US degree-granting institutions

	1995	2005	2015
Faculty/academic (FTE)	677,783	1,290,426	1,551,015
Total (FTE)	2,088,272	3,379,087	3,915,918

With the strong growth in student numbers, there has also been growth in staff employed in higher education. Over roughly the past 20 years the total number of people employed in US degree-granting institutions has effectively doubled, from just over two million people to just under four million people (see Table 11.2). At the same time, the number of faculty or academic staff has more than doubled, from more than 677 thousand to over 1.5 million academics in the United States (adapted from Table 314.10 in NCES 2016).

In Ireland, the number of people currently employed in higher education is approximately 24 thousand, or just over 1% of the labour force. In the United States, approximately 2.4% of the labour force is employed in higher education. The conclusion is simple: universities are large employers. As higher education has expanded, universities have been significant contributors to directly creating jobs, even though this is not typically mentioned in any of their mission documents. A self-study commissioned by University College Dublin (UCD) reports that “the university directly employs just over 4,000 people (3,340 full-time equivalents (FTE’s)), which ranks the university as one of the largest employers in Dublin and would place it among the top 50 private employers overall in Ireland. UCD therefore plays a pivotal role as an employer in the immediate Dublin economy” (UCD 2015). In this study UCD also estimated that it generated a further 3340 full-time equivalent secondary jobs outside of the university, and that student expenditure in the economy resulted in a further 2234 jobs in Ireland. Thus UCD states that the total employment resulting from the existence of UCD is put at 8914 total FTE jobs, with an estimated total annual economic output of €1.3 billion (UCD 2015).

In an example at a different scale, Reuters notes in describing its 2016 rankings for the world’s most innovative universities, “Companies founded by Stanford alumni – including Hewlett Packard and Google ... have upended existing industries and been the cornerstone of entirely new economies”. It cites a 2012 study by Stanford in which it estimated that “all the companies formed by Stanford entrepreneurs generate $2.7 trillion in annual revenue, which would be equivalent to the 10th largest economy in the world” (Reuters 2016).

11.4.3 University Second Mission in support of Job Creation

Universities have other mechanisms for job creation than technology parks and incubators. The entire university, including its research and development activity is in itself a job creation mechanism. André Oosterlinck framed this issue by observing that

> the times during which academic science and technology were largely exogenous to the economic system are over. Academic research now has become much more endogenised and integrated into the economic cycle of innovation and growth. On the one hand, business looks upon academia as a source of scientific novelty and technological breakthroughs to fuel its innovation process. On the other hand, an ever increasing number of academic institutions is becoming fully aware of the economic potential of their research efforts. (Oosterlinck 2004, p. ?)

The USA's National Academy Committee on Measuring Economic and Other Returns on Federal Research Investments, Board on Science, Technology, and Economic Policy, Committee on Science, Engineering, and Public Policy, Policy and Global Affairs conducted a workshop focussing on measuring the impacts of federal investments in research. In the 2011 report of this workshop, rapporteurs Olson and Merrill stated that:

> Based on preliminary results for U.S. metropolitan areas, a positive correlation exists between wages, employment, and academic R and D … The results indicate that a 1 percent increase in academic R and D is associated with roughly 120,000 more people employed and $3 billion more earnings in a metropolitan area. (Olson and Merrill, p. 22)

11.4.4 Third Mission: The Entrepreneurial University

In this section we present findings that point to the economic benefits of an engaged university. The outcomes resulting from a culture of innovation "are the creation and transfer of technology, job and wealth creation, and enhanced recognition and prestige, all of which feed back to, and reinforce, the role of the university" (Smilor et al. 2007, p. 206). It might be argued that a university can be innovative without necessarily being engaged, in the sense of having a vibrant third mission. However, the evidence appears to be strong that the links between industry, especially science-based industry, and the university continue to develop, and the results are good for both. Industry draws increasingly on university research for ideas, while university researchers in turn draw ideas from commercial trends. "Such partnering between university and industry contributes to innovation and growth in the United States and is expected to remain an indispensable element for future economic growth" (Wessner 2011).

Evidence has been developed to show the benefits associated with engaged research universities, and that the nucleus in the development of a dynamic technology center is a research university. If one is not in place, then a technology centre is not likely to develop. Around the nucleus is an organization of talent, money and networks, such as the one that exists around Stanford University. The university's research engine can then generate a vibrant regional economy. These findings have been extended to other research universities outside of the United States, including Cambridge, England (Smilor et al. 2007, p. 204). Research universities are becoming more innovative and entrepreneurial by taking on new roles in a knowledge economy. The research university has become more engaged by more actively promoting technology transfer and commercialization. "As a result, the paradigm of the university has been changing" (Smilor and Matthews 2004).

Silicon Valley is used repeatedly as an example of innovation and job creation success and many regions and countries seek to emulate this success. According to one former president of Stanford University (Gerhard Casper 1998), it was important for Stanford to focus and to stick to the fundamental purpose of a research-intensive university, and this has contributed to its success and the benefit of society. Silicon Valley is recognised the world over for having a productive relationship between a university and the surrounding region. The ingredients that created the productive relationship between Stanford and Silicon Valley have been described by Casper as:

> A commitment to building 'steeples of excellence' in research, learning and teaching; viewing the combination of teaching and research is what we are about, despite innumerable temptations; having the freedom to set agendas; seeking industry partnerships as enrichments to, not distractions from, the research process; maintaining porous boundaries; and being open to chance and serendipity in research. (Casper 1998)

11.5 Role of Government and Policy[1]

There is an ongoing imperative to provide people with rewarding (both economically and personally) work and the converse of avoiding the numerous negative effects of unemployment. "Job creation and destruction are both effects of economic policy, the degree of out- and in-sourcing, and the ability to create new ideas that can be transformed into jobs" (Ibsen and Westergaard-Nielsen 2005).

In the period between the Great War and the Second World War, John Maynard Keynes developed the argument that the level of employment is determined by the spending of money. Keynes (1936) argued that it is wrong to assume that competitive markets will, in the long run, deliver full employment or that full employment is the natural equilibrium state of a market economy. On the contrary, under-employment and under-investment are likely to be the natural state unless active measures are taken. This suggests that it is not just appropriate but necessary for a Government to play an active role in trying to ensure full employment. For example,

[1] This section was originally drafted in 2011 at the height of the worldwide economic crisis. In revisiting it six years later in 2017, the authors note that while the urgency and immediacy of the crisis has ameliorated, the importance of sustainable job creation remains.

the US has been steadily losing manufacturing jobs to other economies, such as China and Mexico. These countries have improved the quality of their manufacturing, as well as their abilities in advanced manufacturing and assembly, while maintaining labor costs below that of the United States (Rattner 2017). During the height of the recent economic crisis, former Intel CEO Andy Grove declared that "job creation must be the No. 1 objective of state economic policy. The government plays a strategic role in setting the priorities and arraying the forces and organization necessary to achieve this goal" (Grove 2010).

If it is accepted that a government should take a more interventionist role in job creation, then what policies, supports and actions should it consider with regard to our universities? This is a question with no one right answer and perhaps no right answer at all. For example, the Irish Government in a 2010 strategy document focussed on economic recovery titled *Jobs and Growth*, states that "the role of Government is to help create the right conditions for enterprise to grow and prosper". This is less of an interventionist role than Grove argues for within the United States. Indeed, the Irish Government summarises its approach as one of providing the *right environment*. "The tax system is purposefully pro-business and fine-tuned to ensure it is internationally competitive. Our regulatory environment is smart and fair and we aim to further improve administrative cost savings for business in our "better regulation" program" (Government 2010). Perhaps a more passionate and direct way to make a similar positive statement was in former US President Barack Obama's speech to a joint session of Congress, on 8 September, 2011, in which he highlighted the importance of jobs in the economy:

> Now, the *American Jobs Act* answers the urgent need to create jobs right away. But we can't stop there. …we have to … start building an economy that lasts into the future – an economy that creates good, middle-class jobs that pay well and offer security. We now live in a world where technology has made it possible for companies to take their business anywhere. If we want them to start here and stay here and hire here, we have to be able to out-build and out-educate and out-innovate every other country on Earth.

The point can be made here that the United States had been successfully out-educating every other country for decades, and that as a consequence it had the best higher education system in the world. Students continue to flock to US colleges and universities, and one estimate has put the number of foreign third level students studying in the United States at almost one million (NPR 2015). What has made US higher education so good? "Competition and a *laissez faire* system, decentralised authority, public funding, gender neutrality, openness, and forgiveness were important in the past for secondary education and continue, in some fashion, to be important for secondary and higher education today" (Goldin and Katz 2008. pp. 259–260).

Countries can take a more interventionist approach to job creation, and seek to create a positive environment to enable job growth. Countries recognise the advantages of a high quality education system, and more and more are investing in their university system. There is evidence that at a macro level, these steps are beneficial. An example of this can be seen in measures to codify the economic competitiveness of individual countries. The World Economic Forum (2016) (www3.weforum.org) publishes a *Global Competitiveness Report*, which provides a snapshot of the competitiveness of the majority of the world's national economies based on a global competitiveness index (GCI). The GCI is structured around the three themes, one of which is *Innovation and Sophistication*. Innovation and Sophistication factors comprise capacity for innovation, quality of scientific research institutions, company spending on R&D, university-industry collaboration in R&D, government procurement of advanced technology products, availability of scientists and engineers, utility patents and intellectual property protection. The countries that rank highly in the *Global Competitiveness Report 2016–2017* all have excellent higher education systems with a strong focus on technology and innovation. In 2016, the top ten ranked countries, in order, were Switzerland, Singapore, United States, Netherlands, Germany, Sweden, United Kingdom, Japan, Hong Kong, and Finland. Other notables include Ireland (23rd), and China (28th).

Notwithstanding a proactive government creating a favourable business environment, and a high quality third level educational system, there are still other (larger) difficulties associated with sustainable job creation. These difficulties result from a shift in corporate power towards shareholder value at the expense of labour within growth oriented corporations. "A new orthodoxy, that corporations existed to create shareholder value, coincided with the rise of information and communication technologies (ICT), in particular the World Wide Web" (Davis 2015). Consequently policy efforts to create good jobs are no longer aligned with shareholder capitalism. The maximization of shareholder value results in a de-valuation of sustainable jobs within the corporation, thereby making any government goal, and indeed university goal, of job creation extremely difficult.

Perhaps as a final comment on the role and effectiveness of policy makers, Steven Rattner makes observations and recommendations regarding the loss of manufacturing jobs in the United States in which he argues that "better training and education are among our best hopes." He recommends a number of policy actions including "better education (particularly in science and maths) and training; higher federal investment spending on infrastructure and research and development; increasing mobility to encourage workers to move to where the jobs are" (Rattner 2017). At the end of the day, if the jobs move, the workers must be prepared to move too. In speaking to a graduating class of MBA students at Harvard Business School in 2001, Jack Welch said that "you can guarantee lifetime employability by training people, making them adaptable, making them mobile to go other places to do other things. But you can't guarantee lifetime employment" (Welch 2001).

11.6 Findings

This chapter has examined the different roles that the university plays in job creation, and wittingly or unwittingly, it has a significant role to play. Figure 11.6 below describes the approach taken to examine these different university roles in creating jobs. Modern universities that embrace, and are capable of successfully

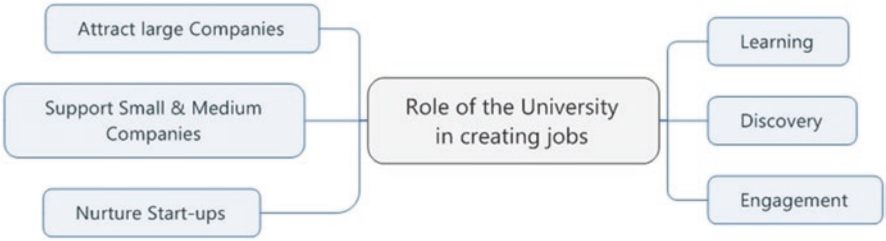

Fig. 11.6 The many roles of the University in creating jobs

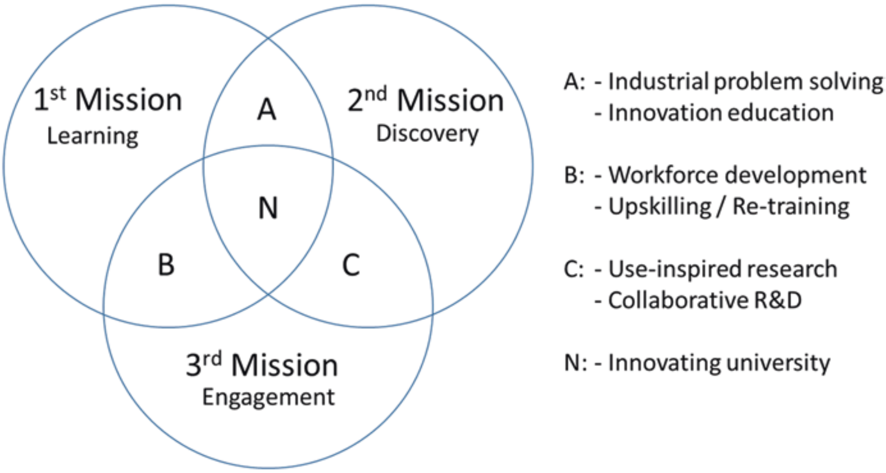

Fig. 11.7 The expanding role of the Entrepreneurial University

blending, their many strengths across all three university missions appear best placed to become such innovative universities. On the right hand side of Fig. 11.6 are the traditional university missions, and it is to these that the university typically devotes its attention. If successful, then we have argued that it can best lead to the successes on the left side of Fig. 11.6 via the attraction of large companies, support for growth of small and medium sized companies, and the nurturing of start-up companies.

The means by which the university can positively contribute to job creation are depicted in Fig. 11.7 as extensions of Learning (first mission), Discovery (second mission), and Engagement (third mission).

In the above figure we have listed just two examples for each of the cross-activities that connect the primary missions of the modern entrepreneurial university. So, for example, workforce development and upskilling/re-training are activities that link first and third missions. We argue that the intersection of the three missions is at the heart of the modern university – and where successful innovative universities such as Stanford, Purdue, KU Leuven, TU Delft, and Dublin Institute of

Table 11.3 University mission impacts on job creation

	1st mission	2nd mission	3rd mission
Type/outcome	Learning	Discovery	Engagement
Attracting large companies	Significant role	Some role	Minor role
Supporting SME	Significant role	Significant role	Significant role
Nurturing start-ups	Minor role	Some role	Significant role

Technology (to name but a few) find themselves. Such universities have assumed a more proactive role in shaping the economies of their regions. For such successful universities:

> The result is the emergence of a culture of innovation that revolves around role models worthy of emulation; personal and organizational networks; enhanced capital resources; and a mindset that encourages tolerance of, and diversity in, the population. The outcomes of this process are the creation and transfer of technology, job and wealth creation, and enhanced recognition and prestige, all of which feedback to, and reinforce, the role of the university. (Smilor et al. 2007, p. 206)

Table 11.3 elaborates on the above figure by indicating estimates of the extent to which each mission contributes to job creation and economic development. It should be noted that each mission has important functions and contributions to make to the desired goal – none is omittable if we seek the maximum impact and effectiveness.

To summarize, the main findings are as follows:

- The quality of the third level education system is critical, in order to create a readily-available high-end workforce. This means the quality of the traditional teaching role of the university must not be overlooked when examining means of job creation, as it generates high-quality graduates. The university must likewise focus on the quality of its educational programs and also maintain close connections with key industry sectors. This can be achieved through a range of collaborative initiatives, including collaborative research and curriculum advisement.
- Countries, or regions, should have an effective continuum of technologically capable people, i.e., a workforce sufficiently diverse and educated to staff their economies. This continuum should range across the spectrum from operatives who can function effectively, through skilled craft workers, technicians, and across to technology-focused engineers and research-focused engineers. Universities clearly generate many technologically capable people. But they are not the sole providers. Community colleges, other non-university colleges and industry-based training programs also generate workforce capability.
- Coordinated and concentrated support from government agencies and universities contributes to effectiveness of job creation.
- While technology parks favour STEM opportunities, incubators need not be STEM-based. As above, coordinated efforts integrating university and government economic development activity with incubator and technology park support offer most promise.

- Job creation is a main underlying purpose of incubator support for new business formation, especially of technology-based firms. However, the evidence is that incubators are not strong job creators, and certainly not as impactful as FDI.
- The combination of strong university first mission role of learning linked with third mission role of industry engagement are significantly important to job creation in the SME sector, the engine of economic growth and job creation.
- With respect to job creation, universities should emphasize use-inspired and market-driven research in addition to curiosity-driven basic research. This also helps keep the university connected to the companies within its region.
- The university should maintain focus on quality with respect to its primary roles, and ensure that mission dilution, or mission creep does not occur. “It is important that the fundamental values of research and teaching are complemented rather than hampered by the university’s active engagement and involvement in the emerging processes of industrial and entrepreneurial innovation and knowledge transfer” (Oosterlinck 2004).

11.7 Conclusion

A review and analysis of the literature and institutional experience leads to the conclusion that the first (teaching/learning) and second (discovery) missions of the university are critically important for economic development and job creation to occur. However, in and of themselves they are not optimal. A focus on third mission (industry engagement) that is aligned with and supports the overall mission of the university appears to be optimal. Systematic and concerted policy and planning support for economic development and job creation appears to be vital. Furthermore it is not sufficient that such planning be done by the university alone. Coordinated planning and actions by the university, in concert with government and the private sector is necessary. However, there is an important cautionary note required in that the university must always be capable of independent thinking and action in order to avoid becoming a directly-controlled instrument of government. A creative tension must be maintained, while acknowledging that some higher education institutions should be more directly aligned with government policy than others.

Strategic planning for the future would benefit from having a reasoned view of alternative futures and their probabilities, such as through scenario planning. Universities are probably better positioned and equipped to generate such scenarios although they will need to involve government, the private sector and society if their findings are to be reliable yet avoid ‘group-think’. Technological change has always influenced jobs, with some developments reducing, or indeed eliminating, jobs while other technological developments have created entirely new types of jobs. As observed by Nathan Rosenberg:

> It seems to be much easier to anticipate the employment-displacing effects of technological change than the employment- expanding ones. Partly this is because we do not have a good technique for dealing with the impact of product innovation. The anticipation of the employ-

ment- expanding consequences of innovations seems to require a much greater exercise of the social imagination, an ability to foresee uses in entirely new social contexts. (Rosenberg 1986, p. 30)

In addition to the above, university value systems, as manifested by both administration and faculty on both sides of the Atlantic, need to appreciate and reward both excellent learning and use-inspired research and development, equally with the rewards for basic research. On a related but separate point, because of the absolute necessity that regions and nations be able to draw on an array of highly capable people to initiate, advance and operate their economic engines, the concept of an array of institutions supplying a spectrum of such capable people is also necessary. This capability needs to be adopted and resourced effectively by policymakers. This also implies that there is no single category of institution that is dispensable, and while their relative importance may vary based on local/regional needs, a viable presence of a range of skills and higher education-based institutions is absolutely necessary.

In closing, we return to Claudia Goldin and Lawrence Katz, who declared:

As technological change races forward, demands for skills - some new and some old – are altered. If the workforce can rapidly make the adjustment, then economic growth is enhanced without greatly exacerbating inequality of economic outcomes. If, on the other hand, the skills that are currently demanded are produced slowly and if the workforce is less flexible in its skill set, then growth is slowed and inequality widens. Those who can make the adjustments as well as those who gain the new skills are rewarded. Others are left behind. (Goldin and Katz 2008, p. 352)

This is the ongoing and relentless race between technology and education, in which the ordinary citizen bears direct witness to this through the quantity and quality of jobs available. The outcomes of the race are either economic growth, or increasing inequality. In this race between technology and education, universities are critical intermediaries.

References

Bertelsmann Foundation (2009). The economic costs of inadequate education: a macroeconomic calculation of the dynamic growth effects of lacking education competence. Available at http://www.cesifo-group.de/ifoHome/research/Projects/Archive/Projects_HI/2009/rest_10244578.html.

Casper, G. (1998). The advantage of the research-intensive University. Accessed December 2011 at http://www.stanford.edu/dept/pres-provost/president/speeches/980503peking.html.

Davis J. (2015). Capital markets and job creation in the 21st century. Report authored by J. Davis. Centre for Effective Public Management at Brookings. December 2015.

Dell, M. (2011). Dell chief 'thrilled' at Irish transition. Interview in *Irish Times*, Business this week section. 2011, Sept 16.

Duderstadt, J. J. (2004). The changing nature of research and the future of the University. Chapter 6. In Weber & Duderstadt (Eds.)., 2004 *Reinventing the research university*. London: Economica.

E3M. (2011). European indicators and ranking methodology for university third mission. http://www.e3mproject.eu/. Accessed Sept 2011.

Enterprise Ireland (2017). Accessed February 2017 at https://www.enterprise-ireland.com/en/about-us/.
Flynn P. (2009). Universities hope merger will create 30,000 jobs. Sean Flynn. *The Irish Times*. Mar 12 2009.
Goldin, C., & Katz, L. F. (2008). *The race between education and technology*. Cambridge, MA: The Belknap Press of Harvard University Press 2008.
Government. (2010). *Jobs and growth*. Dublin: Department of Enterprise, Trade & Employment.
Grove, A. (2010). Andy Grove: How America can create jobs; *business week*. http://www.businessweek.com/magazine/content/10_28/b4186048358596.htm. July 1, 2010. Accessed 18 Sep 2011.
Higher Education Authority. (2011). National strategy for higher education to 2030. In *Dublin: Higher Education Authority accessed June 2017 at* http://HEA.IE/Resources/Publications/national-strategy-for-higher-education-2030.
Hijzen, A., Upward, R., & Wright, P. (2010). Job creation, job destruction and the role of small firms: Firm-level evidence for the UK. *Oxford Bulletin of Economics and Statistics, 72*(5), 0305–9049. https://doi.org/10.1111/j.1468-0084.2010.00584.x.
Ibsen, R., & Westergaard-Nielsen, N. (2005). *Job creation and destruction over the business cycles and the impact on individual job flows in Denmark 1980–2001*, *Working Paper 05-4*. Aarhus: Aarhus School of Business, Department of Economics.
IDA Ireland. (2015). *Winning: foreign direct investment 2015–2019*. Ireland: IDA Accessed February 2017 at http://www.idaireland.com/docs/publications/IDA_STRATEGY_FINAL.pdf.
IDA Ireland (2016). Facts about Ireland, September 2016. Accessed February at http://www.idaireland.com/docs/publications/Facts_about_Ireland_2016.
Kellogg Commission on the Future of State, Land-Grant Universities, National Association of State Universities, & Land-Grant Colleges. (1999). *Returning to our roots: The engaged institution* (Vol. 3). Washington, DC: National Association of State Universities and Land-Grant Colleges, Office of Public Affairs.
Keynes, J.M. (1936). *The general theory of employment, interest and money*. http://en.wikipedia.org/wiki/The_General_Theory_of_Employment,_Interest_and_Money. Accessed Aug 2011.
Landau, R., & Rosenberg, N. (Eds.). (1986). *The positive sum strategy: Harnessing technology for economic growth*. Washington, DC: National Academies Press Accessed June 2017 at: http://www.nap.edu/catalog/612.html.
Lowe, N. J. (2007). Job creation and the knowledge economy: Lessons from North Carolina's life science manufacturing initiative. *Economic Development Quarterly, 21*(339). https://doi.org/10.1177/0891242407306359 http://edq.sagepub.com/content/21/4/339.
Murphy, M., & Dyrenfurth, M. J. (2012). Examining the role of the University in creating jobs. Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. Accessed July 2017 at https://peer.asee.org/21357.
NCES. (2016). *Digest of Education Statistics, 2015*. Publication Number 201614. National Center for Education Statistics. Accessed February 2017 at https://ies.ed.gov/pubsearch/.
NPR. (2015). U.S. colleges see a big bump in international students. November 18, 2015. Accessed on 9 August, 2017 at http://www.npr.org/sections/ed/2015/11/18/456353089/u-s-colleges-see-a-big-bump-in-international-students.
Obama, B. (2011). Address by the President to a joint session of Congress. Accessed June 2017 at http://politico.com/story/2011/09/obamas-jobs-speech-transcript-063043.
OECD. (1997). *Technology Incubators: Nurturing small firms*. Paris: Organisation For Economic Co-Operation And Development OCDE/GD (97)202.
OECD. (2011). *Small businesses, job creation and growth: Facts, obstacles and best practices*. Paris: OECD Accessed June 2017 at http://www.oecd.org/LongAbstract/0,3425,en_2649_34197_2090732_1_1_1_1,00.html.

OECD 2016. *Education at a glance 2016: OECD indicators*. Accessed February 2017 at http://www.keepeek.com/Digital-Asset-Management/oecd/education/education-at-a-glance-2016_eag-2016-en#.WYHaTYTyu70#page44.

Olson, S., & Merrill, S. (Rapps)(2011). *Measuring the impacts of federal investments in research, Workshop Summary for the Board on Science, Technology, and Economic Policy; Committee on Science, Engineering, and Public Policy; Policy and Global Affairs*. Washington, DC: The National Academies Press.

Oosterlinck. (2004). The modern University and its main activities. André Oosterlinck. Chapter 9. In L. Weber & J. Duderstadt (Eds.)., 2004 *Reinventing the Research University*. London: Economica.

Piketty, T. (2014). *Capital in the 21st century*. Cambridge, MA: Harvard Press.

Rattner, S. (2017). Made in America: The bad news and the good bad news. *The New York Times*. June 29, 2017.

Reuters. (2016). Reuters Top 100: The World's Most Innovative Universities – 2016. Accessed July 2017 at http://www.reuters.com/article/amers-reuters-ranking-innovative-univers-idUSL2N1C406D.

Rosenberg, N. (1986). The impact of technological innovation: A historical view. Chapter 1. In R. Landau & Rosenberg (Eds.), *The positive sum strategy: Harnessing technology for economic growth*. Washington, DC: The National Academies Press.

Smilor, R., & Matthews, J. (2004). University venturing: Technology transfer and commercialization in higher education. *International Journal of Technology Transfer and Commercialisation, 3*(1), 111–128.

Smilor, R., O'Donnell, N., Stein, G., & Welborn, R. S., III. (2007). The research university and the development of high-technology centers in the United States. *Economic Development Quarterly, 21*(203). https://doi.org/10.1177/0891242407299426 http://edq.sagepub.com/content/21/3/203.

Tamásy, C. (2007). Rethinking technology-oriented business incubators: Developing a robust policy instrument for entrepreneurship, innovation, and regional development? *Growth and Change, 38*(3), 460–473 September 2007.

Technical Assistance Program. (2015). *Annual report*. West Lafayette: Purdue University, TAP Program Accessed July 2017 at http://tap.purdue.edu/media/1148/annual-report-fy-15.pdf.

Trencher, G., Yarime, M., McCormick, K., Doll, C., Kraines, S., & Kharrazi, A. (2014). Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. *Science and Public Policy, 41*(2), 151–179. https://doi.org/10.1093/scipol/sct044.

Tyndall. (2015). Tyndall National Institute Annual Report 2015. Accessed January 2017 at https://www.tyndall.ie/contentFiles/documents/2015%20Annual%20Report.pdf.

UCD. (2015). Delivering IMPACT: The economic, cultural and social impact of University College Dublin. April 2015. Accessed Feb 2017 at http://www.ucd.ie/t4cms/Delivering_Impact_UCD_April_2015.pdf.

Welch, J. (2001). Jack Welch Class Day Interview -Jack Welch to HBS Grads: "Don't Be a Jerk". Available at http://hbswk.hbs.edu/archive/2310.html. 6 November, 2001.

Wessner, C.W. (Rapporteur). (2011). *Growing innovation clusters for American prosperity: Summary of a symposium.* Washington, DC: National Academies Press, Committee on Competing in the 21st Century: Best Practice in State and Regional Innovation Initiatives; National Research Council.

Wikipedia. (2017). Subaru of Indiana Automotive, Inc. Accessed January 2017 at https://en.wikipedia.org/wiki/Subaru_of_Indiana_Automotive,_Inc.

World Economic Forum. (2016). *The global competitiveness report*. Geneva: World Economic Forum Accessed June 2017 at http://ww3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2016_FINAL.pdf.

Mike Murphy PhD and MEng degrees in electrical engineering from Stevens Institute of Technology. Prior to that he graduated with an Honours Diploma in Electrical Engineering from Dublin Institute of Technology, and BSc(Eng) Honours Degree from Trinity College Dublin. He is a Fellow of Engineers Ireland and a Member of the Institute of Electrical and Electronics Engineers. He is President of the European Society for Engineering Education (SEFI) and is past Chair of the European Engineering Deans Council. He commenced his industry career with AT&T Bell Labs in New Jersey, and later worked with Bell Communications Research before returning to the academy in 2002, when he joined Dublin Institute of Technology as Director and Dean of the Faculty of Engineering. In 2009 he accepted responsibility for the newly formed College of Engineering & Built Environment at Dublin Institute of Technology, which he led as Dean until January 2014. Mike is currently the Academic Registrar at DIT and is Director of Academic Affairs, Digital Campus & Learning Transformation.

Michael Dyrenfurth Ph.D. Industrial Education and Technology & Higher Education, Bowling Green State University; M.Ed. Industrial Education, University of Alberta-Edmonton. Professor, Department of Technology Leadership and Innovation, Purdue Polytechnic Institute, Purdue University, West Lafayette, Indiana, USA. He has been an active leader in the American Society for Engineering Education's Entrepreneurship & Innovation and Engineering Technology divisions, in the Epsilon Pi Tau honorary society for professions in technology, and in establishing the World Council of Associations for Technology Education. His current research focus is on the interface of technological innovation with cognitive science. His publications include Grimson, W., Dyrenfurth, M., & Murphy, M. (2009). Liberal Studies in Engineering & Technology. Chapter 8 in S.H. Christensen, B. Delahousse, & M. Meganck, (Eds.) (2009). *Engineering in Context.* Aarhus, Denmark: Academica and Dyrenfurth, M., & Barnes, J. (2015). *The innovation – cognitive science interface: Implications for engineering and technology education*. Paper delivered at the SEFI (European Engineering Education Annual Conference, July 2, 2015, Orleans, France.

Chapter 12
Costs and Benefits of Commercializing Teaching, Research, and Service in the American Corporatized University

Steen Hyldgaard Christensen

Abstract In the last four decades higher education around the globe has been subjected to a continuous process of reforms as governments have sought to reduce public spending by capitalizing on new commercial opportunities related to education, research, and service in the global knowledge-led economy. Reform efforts have been informed by the dominant economic discourse of neoliberalism originating in the 1970s and the associated discourses of "new public management" from the 1980s. As increased competition represents improved quality in neoliberal discourse a major objective of the reforms has been to implement competition for extramural funding and market-oriented behavior as a way to increase productivity, accountability and control. In the United States in particular, the direction of change has been oriented toward the culture, practices, policies and workforce strategies characteristic of the business corporation which has been seen as an institutional entity providing the basic standards of financial and administrative efficiency. As a result the university is transforming from an educational community with shared governance into a top-down bureaucracy increasingly managed as a traditional profit seeking corporation in which faculty has no meaningful and effective voice. With a focus on the restructuring of higher education in the United States the purpose of this chapter is to examine how the corporatized public research university came about, its distinctive features, and to consider the costs and benefits to the public good of commercializing teaching, research, and service. In so doing the chapter reviews diverse literatures on higher education, academic capitalism, and the corporatized university.

Keywords Academic capitalism · The Corporatized University · Commercialization of higher education · Neoliberalism · New public management · Managerialism

---

The author's interest in the topic is related to the fact that the restructuring of American higher education in many ways has served as a model for reforms in higher education in Denmark.

S. H. Christensen (✉)
Department of Development & Planning, Aalborg University, Aalborg, Denmark
e-mail: steenhc@plan.aau.dk

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_12

12.1 Introduction

In 2003 Henry Steck (2003) – political scientist at the State University of New York – in seeking conceptual clarity regarding the corporatized university, remarked that the notion of the corporatized, corporate or entrepreneurial university is the most ominous buzzword in contemporary higher education in the United States. Today this still seems to be the case. Celebrated by some, rejected by others, the corporatized university always seems to arouse strong sentiments. Not only does it carry sinister connotations in book titles such as *Leasing the Ivory Tower: The Corporate Takeover of Academia* (Soley 1995), *The University in Ruins* (Readings 1996), *The Knowledge Factory* (Aronowitz 2000), *Digital Diploma Mills* (Noble 2002), *University Inc.:The Corporate Corruption of Higher Education* (Washburn 2005), *Unmaking the Public University: The Forty Years Assault on the Middle Class* (Newfield 2008)*, Neoliberalism's War on Higher Education* (Giroux 2014), it is not yet entirely clear what this new entity is, how it came about, and whether it is an appropriate solution to the challenges to which it is supposed to be a response.

Regarding the question whether public non-profit universities have been corporatized, Goldie Blumenstyk – reporter and editor at *The Chronicle of Higher Education* – notes that "most observers would say yes, but there is hardly a common understanding of what the corporatization of college means" (Blumenstyk 2015, p. 121). Blumenstyk mentions a number of secondary markers of the phenomenon such as: corporate CEO-style salaries, the growth of administrative positions including the hiring of vice-chancellors for marketing, the use of branding consultants, the relentless growth in the number of adjunct faculty, tuition models leaving students heavily indebted and compelled to pay loans off while banks profit greatly from procuring the loans and from the interests borrowers pay,[1] universities working closely together with companies to commercialize inventions, and not least the fact that higher education leaders and outsiders increasingly consider students as their customers and education as a commodity, or a product to be delivered to them.

During the last four decades it has been increasingly difficult to maintain public support for state and federally subsidized higher education in the United States. Three main reasons for this predicament need mentioning: (1) the challenge of building a globally competitive post-industrial economy, (2) the mounting costs of an ever expanding higher education system related to massification of higher education, and (3) the long-running fiscal crisis of the state that began in the mid-1970s and which has imposed harsh new realities on both public and private universities as well as colleges. Under these conditions public universities have been forced to generate alternative income streams to keep pace with knowledge change and to demonstrate their direct contribution to the economy (Gumport 2002). As a result the traditional definition of *service* to the public by creating knowledge for free exchange for the benefit of all members of a given society has changed. The public

[1] Presently student loans amount to an alarming all-time high of $1,43 trillion. For the current magnitude of loans see e.g. www.usdebtclock.org

university has therefore increasingly come to serve as a provider of human capital and commodifiable knowledge and has down-toned its role as an educational institution preparing students for citizenship.

Corporatization of the university thus enables the withdrawal of state responsibility for the provision of education by cutting appropriations for higher education and by redirecting the responsibility for funding to individual students (Lave et al. 2010; Bok 2003). This means that each time there is a downturn in the economy and a reduction in tax revenues universities tend to compensate for the loss of public funds by increasing the prices they charge their students. According to David F. Labaree (1997) the present goal of higher education in the United States is *social mobility* in which "education is a commodity, the only purpose of which is to provide individual students with a competitive advantage in the struggle for desirable social positions" (ibid, p. 42). Consequently higher education has been redefined as a private investment and as a positional good in a zero-sum game of getting a "good" job and its associated lifestyle. A main effect of commodifying education has been that the higher the prices universities charge their student, the more the students insist that their education needs to be relevant, crowning their efforts in the kind of job that will enable the graduate to recover the costs of enrolment (Zemsky and Duderstadt 2004). A main effect has therefore been a trend towards a more vocationalized curriculum.

Another impact of the emphasis on commercialization is that the link between teaching and research as mutually reinforcing activities has been broken. James J. Duderstadt (2004, p. 80) notes that in most research universities "there is an ever-widening gap between the research activities of the faculty and the undergraduate curriculum". Thereby teaching has been reduced to a secondary function while profitable knowledge production has become the primary function of the university. The conduct of this kind of research is characterized by a narrowing of research agendas to focus on the needs of commercial actors. With respect to teaching many universities have started outsourcing the teaching function or replacing tenured faculty with adjunct and contingent faculty hired on short term or at-will contracts (Lave et al. 2010). Moreover it has been argued that information technologies have undermined the role of faculty, increased the power of administrators and failed to serve the students well (Noble 2002).

The transition to the corporatized public university has been conceptualized by Patricia J. Gumport in terms of a change in the dominant legitimating idea of public higher education. According to this conceptualization the dominant legitimating idea has thus changed from higher education as a social institution to higher education as an industry (Gumport 2000). Furthermore Adrianna Kezar (2004) has conceptualized the relationship between the two legitimating ideas of the public university in terms of a *social charter* or *contract* between the public university and society. Kezar's conceptualization includes three different understandings of the public good reflected in three different social charters. The philosophical underpinnings of these understandings of the public good are derived from communitarian, neoliberal, and utilitarian philosophies respectively. *The communitarian philosophy of the public good* is reflected in a social and public charter associated with the traditional model of the public university as a social institution responsive to social expectations. *The neoliberal philosophy of the public good* promotes an individual and economic charter, resulting in the industrial model of the public university responsive to market forces. Finally *the utilitarian model of the public good* advocates a changing and contested charter that is a blending of the traditional model of the public university as a social institution and the industrial model of the public university responsive to both social expectations and market forces.

In the United States, like in many other countries, the restructuring of higher education has been informed by the dominant economic discourse of neoliberalism originating in the 1970s and the associated discourses of "new public management" from the 1980s. The new neoliberal governmentality in university management has placed economic efficiency and managerialism at the core of its operating philosophy and has thereby radically changed the organization and ethos of higher education. Its *modus operandi* has been based on a strategy of "selective excellence" resulting in "downsizing", "restructuring", "program reduction", and "program elimination". Hence the response to the long-running fiscal crisis has been austerity as debt-based investment has not been seen as a viable option to pursue. Program elimination has in particular taken place in those academic areas that are deemed of insufficient centrality, quality, or cost-effectiveness (Gumport 1993, 2000). As a result the split between the "two cultures" – the sciences and engineering versus the humanities and the social sciences – has been deepening (Slaughter and Rhoades 1996). Henry Steck (2003) puts it this way:

> Nor is it any wonder that so much of the critique of the modern university flows from the pens of humanists, social scientists, and lit-crit types for whose work there are no patents, no technology transfer, no strategic plans, and but for a few superstars, no super incomes, and who constitute the pockets of resistance to the changes in the university. (Steck 2003, p. 75)

Not least has the ethos of higher education been changed as a result of rigorous assessment procedures related to the new accountability regime. More precisely has this regime profoundly altered the academic workplace by imposing organizational and individual performance metrics on every aspect of higher education (Gumport 2000). Manfred B. Steger and Ravi K. Roy (2010) have provided a useful working definition of the neoliberal governmentality which triggered the introduction of the new accountability regime:

> Rather than operating along more traditional lines of pursuing the public good (rather than profits) by enhancing civil society and social justice, neoliberals call for the employment of governmental technologies that are taken from the world of business and commerce: mandatory development of "strategic plans" and "risk management" schemes oriented toward the creation of "surpluses"; cost-benefit analyses and other efficiency calculations; the shrinking of political governance (so-called best practice governance); the setting of quantitative targets; the close monitoring of outcomes; the creation of highly individualized, performance-based work plans; and the introduction of "rational choice" models that internalize and thus normalize market-oriented behavior. Neoliberal modes of governance encourage the transformation of bureaucratic mentalities into entrepreneurial identities where government workers see themselves no longer as public servants and guardians of a qualitatively defined "public good" but as self-interested actors responsible to the market and contributing to the monetary success of slimmed-down state "enterprises". (Steger and Roy 2010, pp. 12–13)

In what follows the first section briefly outlines the history of how the corporatized public university came about in the U.S. through a bipartisan "competitiveness" R&D policy coalition which succeeded in adapting legislation to a new narrative of science and technology. In the subsequent section the distinctive features of the corporatized university will be uncovered and presented in an ideal typical fashion. This is followed by a third section which considers the costs and benefits to the public good of commercializing teaching, research, and service.

12.2 A Brief History of How the Corporatized University Came About in the U.S. Through Change of the Science and Technology Narrative

Since the 1980s American public research universities have increasingly come to resemble transnational profit seeking business corporations as they have become integrated in the new global knowledge-led economy. A variety of factors has contributed to the internationalization of universities. Prominent among them are international flows of faculty and students, curricular content, collaborative cross-border research, emergence of branch campuses, intergovernmental agreements, links to transnational corporations, and global rankings. But most importantly, from a macro-perspective, they have now become an integral part of the American innovation system with the purpose of strengthening the nation's global competitiveness by patenting the results of research, and by promoting advanced applied technology, technology transfer, and the training of a competitive scientific and professional labor force. In particular a new sector of high technology including the life sciences, information technology, and biotechnology has become a key area in the knowledge-based economy (Kauppinen et al. 2016).

The American discourse on "economic competitiveness" emerged during the late 1970s and early 1980s as a discourse that differed significantly from the Cold War discourses of "winning the fight against communism" and "the war against disease".

During the Cold War period the university model as a social institution espousing a *communitarian social charter* had its greatest moment as public investment in higher education was seen as crucial to meet the need of a growing population and the increasing demand for higher education stemming in no small part from returned military veterans in 1945. As a result increasing numbers of middle- and working class students entered college. This democratization of higher education was made possible by the expansion of inexpensive public universities, generous grants and scholarships, and low-interest loans (Schultz 2015). The Cold War consensus included both the importance of an educated populace as well the importance of research. Generous public funding of education and research was seen as an important part of the effort to achieve technological and political supremacy over communism.

The discourses on the type and value of scientific research had their origin in a report written by a study group chaired by Vannevar Bush, the director of the war-time Office of Scientific Research, and a former MIT professor and dean. In 1944 President Franklin D. Roosevelt had asked Bush to consider how the lessons which had been learned from research and development during the war could be applied in the post-war period. Bush reported to the President in July 1945 in his famous report *Science, the Endless Frontier; A Report to the President on a Program for Postwar Scientific Research.* In the report Bush linked industrial progress and success in world trade with basic curiosity-driven research:

> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn…..Today, it is truer than ever that the basic research is the pacemaker of technological progress…..A nation which depends upon others for its new basic scientific knowledge will be slow in industrial progress and weak in its competitive position in world trade, regardless of mechanical skills. (Bush 1945, p. viii)

In his Introduction Bush set forth three basic premises: (1) scientific progress is essential, (2) science is a proper concern of the government, and (3) freedom of inquiry must be preserved (ibid, pp. 10–12). Regarding the second premise it should be noted that federal support for basic research rose 25-fold from 1948 to 1968 in real dollars to reach almost $3 billion per year (Bok 2003).

According to Sheila Slaughter and Gary Rhoades (1996) during the post-war 1945–1970 period two strong R&D policy coalitions including both Republicans and Democrats were formed around these Cold War discourses. The first was the defense coalition related to the military-industrial complex. The goal of this coalition was to: (1) win the Cold War, (2) administer high profits to defense corporations and indirectly their contractors and suppliers, and (3) subsidize corporate and academic R&D. The mission agencies included Department of Defense (DOD), Department of Energy (DOE), and National Aeronautics and Space Agency (NASA). Federal R&D funding was channeled through these mission agencies. The second bipartisan coalition emerged through the National Institutes of Health (NIH) related to the medical-industrial complex. This complex was formed by physicians in private practice, non-profit hospitals and insurance companies, pharmaceuticals, university administrators, and many research professors. The goal of the NIH coalition was to: (1) win the war against disease, (2) administer high profits to specialist physicians and pharmaceutical companies, and (3) subsidize corporate and academic research. In the extension of Bush's report a common feature of the coalitions' public discourse about science and technology was an emphasis on basic science carried out in university ivory towers in which scientists and engineers would develop "seed corns" from which national security, health and prosperity would grow (ibid., p. 316). The possibility to build separate research institutes or academies was also initially considered, but the federal government decided to rely on partnerships with leading American universities which were to be supported through a system of competitive, peer-reviewed grants and a framework for contractual relationships between universities and government sponsors (Duderstadt 2004).

In the late 1970s and early 1980s, an emerging "competitiveness" R&D policy coalition began to promote a new narrative of science and technology. This coalition also gathered bipartisan support. In this narrative business and industry were seen as working closely together with science and technology to create commercial products and processes that would make the United States more competitive in global markets. The new narrative was a strategic response to a number of destabilizing events: the end of the Cold War, the end of Keynesian-style controlled capitalism having led, it was argued, to the creation of self-serving bureaucracies and economic stagflation, the rise of the Pacific Rim countries as economic competitors in particular the challenge from Japan, and the possibilities presented by intellectual property. What was new in this narrative was that the needs of business and industry were presented as paramount. University-based scientists and engineers played only a secondary role. In the new knowledge regime knowledge was valued not for its own sake or how in a long-term perspective it might contribute to economic development. Knowledge was paramount for its contribution to the creation of products and processes for the market at the moment (Slaughter and Rhoades 1996). This was a move from curiosity-driven basic research towards the conduct of more applied research for industry.

As public universities were seeking to create alliances with industry from the late 1980s onward they were not only helping the nation to respond to the macro-economic challenges mentioned above, from a micro-perspective they were also individually engaging in academic capitalism through their academic staff (Slaughter and Leslie 1997; Slaughter and Rhoades 2004). This happened when the academic staff of publicly funded universities operated in an increasingly competitive environment, in which they made use of their academic capital, comprising teaching, research, consultancy skills or other applications of forms of academic knowledge, to pursue private sector funding. Even though they were still public employees, the fact that they began using market-like behavior may have started to detach them from the idea that they were public employees. They had thus become state-subsidized entrepreneurs. This group also included academics moving from curiosity-driven basic research towards the conduct of more applied research for industry (Deem 2001). Competition among universities in turn produced greater efforts to lift their reputation – to be documented in league tables and university rankings – by recruiting outstanding new professors, financing merit scholarship to attract better students, and providing salaries and facilities needed to keep highly reputed faculty from leaving, thereby amplifying the need for additional funding or a redistribution of existing funding (Bok 2003).

In keeping with Slaughter and Leslie (2000) it was research funding for science, mathematics, and engineering (SME) that originally drove academic capitalism. From the 1980s the SME share of research funding increased while funding for most other fields decreased. SME brought grants and contract revenues to colleges and universities as their potential to yield intellectual property was higher compared with other fields. The prospect of a "big hit" with patents able to generate a continuous stream of royalties from patent licenses was a strong driver for expanding opportunities for academic capitalism. Every research university hoped to patent something similar to recombinant DNA technology.

Jennifer Washburn (2005) has pointed out that it was the mounting concerns about declining productivity and rising competition from Japan that prompted the U.S. Congress to pass the Bayh-Dole Act in 1980. The act enabled public universities to patent federally-funded research on a large scale for the first time, and it gave public universities the opportunity to license campus-based inventions to private companies in exchange for royalties or other fees. Prior to the Bayh-Dole Act patentable inventions and processes developed through public funding remained in the possession of the federal government, which thus held patent rights as the trustee of the public. Research funded by the public could only be licensed for public benefit (Newfield 2003). The Bayh-Dole Act revolutionized university-industry relations and gave new and concrete meaning to the phrase "commodification of knowledge". Together with ensuing legislation it also served to blur the boundaries between public and private sectors. Subsequent legislation also intent on fostering closer university-industry ties included tax breaks for corporations willing to invest in academic research (Washburn 2005; Boesenberg 2015). With respect to the magnitude of the effect of the Bayh-Dole Act, noted that by the end of the 1980s two hundred universities had established patent, technology-licensing and/or technology transfer offices. Moreover at the turn of twenty first century the volume of their patents had increased 10 times with the result that they were now earning more than $1 billion per year in royalties and license fees. On top of that more than thousand collaborative arrangements had been put in place with local companies, and in addition centers were created to provide technological assistance to small businesses. Finally in several universities companies founded by their professors came to be supported by investments from special venture capital units.

> By all accounts, these initiatives achieved their purpose. Within a decade, two hundred universities had established offices to seek out commercially promising discoveries and patent them for licensing to companies. By the year 2000, universities had increased the volume of their patenting more than 10-fold and were earning more than $1 billion per year in royalties and license fees. Some twelve thousand academic scientists were participating in more than one thousand collaborative arrangements with local companies. Many campuses had created centers to give technological assistance to small businesses or developed incubators offering seed money and advice to help entrepreneurs launch new enterprises. Several institutions formed special venture capital units to invest in companies founded by their professors (Bok 2003, p. 12)

The Stevenson-Wydler Technology Innovation Act of 1980 worked in the same direction in making it easier for federal laboratories to transfer technology to non-federal entities and by providing outside organizations with a means for accessing federal laboratory technologies, thereby establishing the legal and administrative frameworks for transfer between public and private entities.

The Small Business Innovation Development Act of 1982 stipulated that federal agencies with more than $100 million should devote 1.25% of their budget to research carried out by small companies which were seen as the engines of economic recovery (Slaughter and Rhoades 1996). The act was passed in spite of opposition from major research universities. Eleven mission agencies were included in the act. For universities in particular the National Science Foundation (NSF) was relevant. Compared with the overall budget of this mission agency the proportion that went to the Small Business Program was insignificant, but according to Slaughter and Rhoades (1996) it "symbolized the inability of the research university lobby to hold its share of federal dollars when it acted outside the purview of the competitiveness R&D coalition" (ibid, p. 319).

Incentives for the medical-industrial complex to embrace the "competitiveness" agenda were created through the Orphan Drug Act of 1983 and the National Cooperative Research Act of 1984. These acts reflected the increasing importance of research in business strategies. In such business strategies research enables product development, promotes government subsidies, and serves legal and ideological functions. The act of 1984 served to weaken national antitrust legislation which was a clearly ideological manoeuvre. The Orphan Drug Act provided incentives to facilitate development of orphan drugs for rare diseases such as Huntington's chorea, myoclonus, ALS, Tourette syndrome and muscular dystrophy which affect small numbers of individuals in the U.S. It provided tax incentives and incentives to create market monopolies, and stimulated biotechnology firms which drew heavily from academic federally funded R&D to pursue niche markets for vaccines and diagnostics for rare diseases.

Overall, the series of acts from 1980 to 1994 may be seen as embodying the "competitiveness" policy coalitions' strategy towards global control of intellectual property. Moreover in the 1980s and 1990s the core neoliberal goal of establishing a single global market found its partial realization in major regional and international trade liberalization agreements such as NAFTA and GATT (Steger and Roy 2010). This new global economic order was largely an American creation. However to put the economic "competitiveness" discourse and the associated neoliberal reforms into perspective it should be mentioned that the U.S. trade deficit by 20. February 2017 was $734 billion and the U.S debt held by foreign countries was $5.9 trillion, with China and Japan as the greatest creditors. These figures should be related to the magnitude of the U.S. gross domestic product which was $18.9 trillion (www.usdebtclock.org). Whether these macro-economic figures are suggestive of a failure of the economic "competitiveness" discourse and associated neoliberal reforms is difficult to say and would need more detailed analysis. Still, even in spite of the financial crisis that broke out in 2008 in common understanding a competitive economy would be expected to perform better and to show a trade surplus.

12.3 The Distinctive Features of the Corporatized University

For the present purpose the corporatized public research university is defined as an institution in which the business corporation provides the basic standards of: (1) financial and administrative efficiency, (2) organizational culture, (3) control of academic labor, (4) definition of students, (5), and definition and control of ancillary revenues. Departing from the five elements in the definition, an ideal type of the corporatized public research university is composed below.

12.3.1 Financial and Administrative Efficiency

1. CEO-style management and corresponding salaries as incentives for performance optimization (Soley 1995).
2. Extending the jurisdiction of the university president – the chief CEO of the institution – to almost everything that takes place on campus (Soley 1995) sometimes also including the curriculum (Schultz 2015).
3. Recasting research and teaching to become amenable to bureaucratic administration and adjustment in order to adapt to the generic management skills that managers often with corporate backgrounds bring to the organization (Valsan and Sproul 2008).
4. Bureaucratic accretion resulting from increase of personnel in administrative positions (Gumport and Pusser 1995).
5. Redefining university departments and other units as fiscally self-sustaining "revenue centers" in which sustainability is to be ensured through responsibility-centered management.
6. Re-conceptualizing teaching as a profit center (Slaughter and Leslie 2000).
7. Reinforcing the trend toward larger classes and more impersonal learning for students to achieve cost-effectiveness (Kezar 2004)
8. Establishing patent, technology-licensing and/or technology transfer offices to patent and license campus-based inventions to companies enabling the university to earn royalties from licenses in return (Press and Washburn 2000).
9. Hiring teams of lawyers to defend ownership and intellectual property rights derived from research and teaching (Duderstadt 2004).
10. Buying equity stakes in companies whether start-ups or existing that stand to profit from faculty research (Press and Washburn 2000).
11. Establishing business incubators and science parks to support job creation in the region.
12. Imposition of standards of efficiency, cost-effectiveness, and appeal to students in decisions related to the future of academic programs.
13. Implementation of total quality management and reliance on quantitative metrics of evaluation.

14. A customer service orientation. Service is understood to mean assisting the nation's economy by producing an educated workforce and commodifiable knowledge to support the market (Palmadessa 2015).

12.3.2 Organizational Culture

1. Implementing the culture, values and practices of the business corporation thereby transforming academic values into corporate values.
2. Emphasis on entrepreneurial values and practices enabling faculty entrepreneurs to become academic capitalists (Gumport 2000; Slaughter and Rhoades 2004). Faculty members are provided with incentives to treat their teaching, research and service as commodities to be sold at a profit for the institution with the aim of reducing the institution's responsibility for faculty salaries (Kezar 2004).
3. Vocational drift of curriculum shifting away from a general or liberal arts education towards disciplines closely related to fields such as engineering, computer science, and management focused more on training or information-based delivery than on developing higher order intellectual skills (Kezar 2004).
4. Abandoning the traditional cultural norms of faculty and students focused on the close link between teaching and research (Barrow 2010).
5. Emphasis on branding and mission statements including vision, values and excellence, the "products" university mission statements sell to students to ensure growth of student enrollments and corresponding revenues from tuition and fees (Sauntson and Morrish 2011).
6. Using prestige brands to signal increased selectivity and high tuition in marketing the university to the most affluent demographic segments (Newfield 2004).
7. Hierarchical organization and growth in levels of middle-management lacking the formal symbols that convey legitimacy within the university such as for example an earned doctorate in a substantive field (Barrow 2010).
8. Strategic planning geared towards selective excellence in R&D fields (Barrow 1996).
9. Benchmarking, productivity measures, and emphasis on institutional goals to be achieved.

12.3.3 Control of Academic Labor

1. Using a just-in-time approach to teaching which entails employing growing numbers of part-timers in the form of contingent labor, and teaching assistants hired on short term or at-will contracts as a flexible and easily disposable low-cost labor force. Just-in-time hiring takes place in the weeks or days before classes start. At-will contracts condition a disconnect of contingent faculty from their peers and students in time and place (Rhoades 2013).

2. Promoting depersonalized curricular delivery models that alienate and separate faculty and students from the educational programs in which they are enrolled (Rhoades 2013).
3. Following a de-professionalization strategy in treating professors as managed professionals rather than autonomous professionals (Rhoades 1998), and either implicitly or explicitly requiring from them that they should submit to the ethics of competition and performance as a replacement for their traditional belief in the ethics of professional judgement and cooperation (Ball 2003).
4. Eroding tenure, the traditional pillar of the professoriate (supported by arguments such as the one put forward by James F. Carlin (1999, p. A76) "that lifetime jobs border on being immoral").
5. Promoting salary differentials both among academic fields and within them favoring business, agriculture, engineering, and the life sciences (Szelényi and Goldberg 2011).
6. Using alternative criteria of judgement, such as the amount of external research funding a faculty member brings home to the institution as a criterion for appointment, renewal, promotion, tenure, and access to laboratories (Steck 2003).
7. In tandem with corporate sponsors the university strives to gain control of faculty's intellectual property rights.
8. Unbundling teaching and teaching materials to facilitate distance learning. Unbundling extends the thinking descending from Frederick W. Taylor's principles of scientific management. Unbundling concerns course design, material collection and module preparation. Module preparation is therefore no longer based on the judgment and creativity of a single professor, teacher and possible colleagues. Instead module preparation has become the task of an unrelated team (Steck 2003). Eyal Press and Jennifer Washburn (2000) argue that in a time of "budget shortfalls and dwindling public support for education, university administrators and politicians see online education as a way to expand on the cheap" (ibid, p. 20).
9. Faculty resistance as a self-defense mechanism against corporate business practices through the formation of faculty unions including tenured as well as teaching assistants and adjunct faculty (Steck and Zweig 2000).

12.3.4 Definitions of Students

1. Defining the student as a customer or variously as a consumer entails that the customer is always right and must be catered for to his or her full satisfaction thereby reversing the relationship between the student learner, the role of the teacher, and curriculum construction. The British sociologist Frank Furedi (2011) argues that "from a Socratic perspective the very term "student satisfaction" is an irrational one…..Because students need to be placed under intellec-

tual pressure, challenged to experience the intensity of problem solving. Such an engagement does not always promote customer satisfaction" (ibid., p. 4).

2. Students increasingly see the university as a simple service provider, a convenience store for credentialing or self-enrichment. Credentialing is reflecting the changing value of educational degrees on the job market and is largely supply-driven through the expansion of higher education and schooling which in turn have led to credential inflation (Collins 2002).
3. The predominance of the belief that a university degree is a private good and therefore an investment that must be paid for by the student and her or his family. A corollary of concerns follows suit: marketing the product, forms of promotion by means of slogans such as "students come first", "excellence", or "welcome to the university". Not least determining customer satisfaction through the metrics of surveys. Positive results from student satisfaction surveys are an important aspect of university benchmarking together with other aspects such as service, quality, and affordability (Steck 2003).
4. Defining excellence through selectivity. Selection of high caliber students to emulate the most selective universities in the United States – Princeton, Stanford, Cornell, Duke, and Penn (Newfield 2010).

12.3.5 Definition and Control of Ancillary Revenues

1. The campus space, once a gathering place of a community of scholars and students secluded from the outside world, has been transformed into a commercial space akin to the shopping mall (Steck 2003).
2. Starbuck, McDonalds, Taco Bell, Barnes & Noble furnish students and faculty alike with their products through campus cafeteria and bookshops. These business corporations have been allowed to offer their products through marketing agreements, sponsorships, sales, signs and licensing deals creating additional income streams for the university (Steck 2003).
3. Commercializing the campus and campus culture also includes revenues from athletics, conferences, facility rental, food courts, clothing with university logos, etc. (Steck 2003).
4. The sponsoring of campus activities in the corporatized university goes beyond the prior naming of buildings or entire schools after wealthy donors.
5. Promoting the corporatized university through logos akin to advertising designs rather than the classic Latinate seals (Steck 2003).

The subsequent section considers the costs and benefits to the public good related to the restructuring of the public research university along the industrial model embodied in the notion of the corporatized public research university.

12.4 Costs and Benefits to the Public Good Related to the Corporatization of the Public Research University

The question whether the corporatized university is an appropriate solution to the challenges to which it is supposed to be a response will be considered by addressing four issues with regard to the costs and benefits they have produced to the public good. These are: corporatization of management, privatization and commercialization of research, faculty commitment conflict and disempowerment, and vocational drift of curriculum and weakened teaching.

12.4.1 Corporatization of Management

As stated by Christopher Newfield (2003) higher education in the United States has always had a strongly corporate-oriented structure with strong ties to business not least through the dominance of business interests among members of the boards of trustees. Nevertheless during the twentieth century faculty had more influence on governance and management than in any previous period. In the 1970s, however, critics came to see shared governance as a problem since faculty was described as too self-interested to make sound decisions with respect to the overall good of the institution. This was in particular the case when program reduction was on the agenda. As a result corporate governance began to assert itself and a corporate revolution took place in the 1980s enhanced by activist members of boards of trustees who took more control over institutional governance. In the past four decades decision-making has thus become increasingly centralized in boards of trustees and presidents of universities.

Presently, as pointed out by David Schultz (2015), trustees, chiefly business leaders, with minimal input from the faculty select university presidents, who in turn and again often without guidance from faculty select deans, department heads, and other administrative personnel. Only occasionally has faculty been consulted but generally faculty has no meaningful and effective voice. Especially concerning strategic decisions regarding for-profit activities and distance education which needed to be made, very little faculty consultation seems to have taken place (Kezar 2004). Australian higher education scholar Simon Marginson has articulated the following anxieties about the new corporate top-down management style:

> Over and over again, it became apparent that those in position of greatest influence in the university were often fixated on simplistic norms of good management. There was a loss of the sense of the distinctive character of universities, a forgetting of what it is that they do, and what makes them different from other institutions, and an undue faith in generic organizational models. (Marginson quoted in Kezar 2004, p. 440)

On top of that the very nature of presidential leadership has changed. Traditionally presidents acted in the role as intellectual and moral leaders. Now it appears that they spend most of their time in fund-raising, promoting their institution, establishing corporate partnerships, and developing entrepreneurial activities.

Among supporters of the corporate approach to university restructuring the belief that cost reduction will help facilitate greater access to higher education has appeared to be unfounded. Strategies such as total quality management and outsourcing of faculty may have worked positively in limited situations but on the whole the way they affect the university has been negative. Unsurprisingly outsourcing of faculty has instead led to declining staff and faculty motivation. It has also been documented that many trustees do not have the educational expertise to make well-informed decisions. This kind of decision-making is detrimental to the teaching and learning environment. In summing up the threat to the public good Kezar notes:

> The threat to the public good from corporate approaches noted by critics is confirmed by evidence and includes loss of societal leadership from college presidents and other educators; a lack of democratic governance which aids in implementing policy; less-informed governance decisions; decreased commitment and motivation from staff; and the further degradation of teaching and learning environments. (Kezar 2004, p. 445)

From a neo-Marxist perspective Clyde W. Barrow (2010) has argued that the attempt by university administrative systems to simultaneously respond to the three contradictory challenges mentioned at the beginning of the chapter, namely those of (1) building a globally competitive post-industrial economy, (2) coping with the demand for increased access to higher education, and (3) coping with a fiscal crisis, has led to a functional collapse and disorganization of public universities which he describes as a rationality crisis in higher education. As mentioned previously from the early 1990s state managers began linking resource allocations to a strategy of selective excellence including the development of centers of excellence that depended on strategic planning envisioning an extended fiscal crisis. The rhetoric of selective excellence entails that comprehensive field coverage is increasingly considered too expensive to be a viable option to aspire to for every campus (Gumport 2000).

According to Barrow strategic planning develops into a fictitious rationality when it divorces itself "from social or organizational ends and no longer subjects itself to the evaluative requirement that it be functionally effective" (ibid, p. 321). In divorcing themselves from these ends administrators in charge of strategic planning and operation develop into a self-serving bureaucracy exhibiting the behavior of a caste. Barrow describes fictitious rationality as the *modus operandi* of the present administrative system where managers monitor and regulate academic work, rather than produce educational values, such as teaching or research. Fictitious rationality is thus "the ideological illusion of individuals who observe the academic labor process, but are not part of that process" (ibid. p. 321).

Barrow further argues that even though the business corporation furnishes the basic standards of financial and administrative efficiency, at the pinnacle of strategic planning by the mid-1960s its shortcomings in business corporations were already in evidence. By the 1980s this kind of business planning and decision-making system had been abandoned by American business corporations in favor of leaner, flatter, and more flexible forms of organizations and decision-making associated with post-Fordism. Instead of emulating the leaner, flatter, and more flexible business corporation the proportion of administrators to professors has increased in colleges and universities. In 1975 the work of 446,830 full-time professors was supported by 268,952 administrators and staffers. Over the next four decades the number of full-time professors grew slightly more than 50% following the percentage growth of student enrollments in the same period whereas the number of administrators increased by 95% and administrative staffers by 240%. According to Blumenstyk the latest available data from The Department of Education show that the number of full-time "executive, administrative, and managerial" employees at all degree-granting colleges increased by more than 58% between autumn 2001 and autumn 2011, compared to an increase of 23% for the number of full-time faculty (Blumenstyk 2015, pp. 92–93).

12.4.2 Privatization and Commercialization of Research

As it was made clear in Sect. 2 the legislation that enabled the Competitiveness R&D Policy to emerge, most notably the Bayh-Dole Act of 1980, transformed intellectual property from being a by-product of knowledge production to becoming the essential goal of scientific discovery. Interestingly, as reported by Leonard Minsky (2000, p. 96) Admiral Hyman Rickover – known as the Father of the American Nuclear Navy - in 1980 testified against the Act and "warned that its implementation would be disastrous for the universities and basic research". When he was about to retire he testified for the last time before the Joint Economic Committee of the United States Congress reminding its members that it had been a long standing policy of the government "to preserve for the American taxpayer title to the inventions developed by government contractors at the public expense" (ibid, p. 96). Ignoring his warning the passing of the Bayh-Dole Act enabled industry to benefit from an existing academic research infrastructure, thereby paying only a fraction of the actual costs of conducting research.

Examples of costs to the public good can be found in areas such as medical research which has become big business with technology transfer offices that sell research findings to pharmaceutical and biotechnology firms (Soley 1995). In addition to receiving corporate funding to finance their research, biomedical researchers frequently receive stocks or stock options from the supporting pharmaceutical corporation. This tactic of incentivizing the biomedical researcher means that "if the researcher makes an important discovery the stocks soar in value and the researcher becomes rich or at least better-off financially" (ibid. p. 43). It is not astonishing that this kind of incentive can corrupt the integrity of research. Conflicts of interest are but one example that can compromise research, other examples abound in public and private research universities alike such as manipulation of manuscripts before publication to serve the commercial interests of the pharmaceutical firm, delayed publication for more than 6 months to protect proprietary information. Eyal Press and Jennifer Washburn (2000, p. 5) quote a leading cancer researcher who says that "one of the most basic tenets of science is that we share information in an open way…..As biotech and pharmaceutical companies have become more involved in funding research, there has been a shift toward confidentiality that is severely inhibiting the interchange of information…..The ethics of business and the ethics of science do not mix well".

Press and Washburn (2000) also report that "a study of major research centers in the field of engineering found that 35 percent would allow corporate sponsors to delete information from papers prior to publication" (ibid, p. 6). Although the integrity of research can be corrupted in several ways the magnitude of the problem is unknown since it would be extremely complicated to document. Still however the numerous examples of corrupted research practices which can be derived from single cases associated with the commercialization of research show that the compromises to the public good are considerable (see for example Washburn 2005). The ethos of modern science was traditionally understood in terms of Robert K. Merton's CUDOS norms: communism, universalism, disinterestedness, and organized skepticism. "Communism" signified that scientific discoveries and knowledge production are the products of social collaboration and should be considered the common property of the community to be used freely by everyone. Secrecy is the antithesis of this norm, whereas full and open communication is its enactment. In commercial research these norms no longer apply (Slaughter 1988).

On the positive side it should be noted that there are also a number of major benefits from the commercialization of research that serve the public good. First among them is the fact that the regional economy can benefit greatly from technology transfer and privatization of research by establishing university-company partnerships in new areas with economic growth potential. Secondly, corporations, small- and medium-size businesses whether entering in university-company partnerships or not are main sites of job creation able to provide job opportunities for graduates and growth opportunities for faculty members who teach at the university. Thirdly, corporations and other companies can provide funding and facilities to students. On the one hand this kind of arrangement allows universities to reduce their student related expenditures. On the other hand from a learning perspective it can provide students with opportunities for on-site experience and learning. Finally companies can supply expert employees who are interested in entering universities as part-time adjunct faculty.

12.4.3 Faculty Commitment Conflict and Disempowerment

In the move from serving students to serving the economy managerial expectations of faculty have changed. According to Slaughter (1985) since the 1980s managers have expected faculty to be more productive in specific ways. Faculty is now expected to train students for "high tech, high cost, high return" jobs, to secure more and more research funding, and to serve the public by linking research to industrial revitalization. To better understand managers' changing expectations, they should be seen in the context of changes taking place in national leaders' expectations of education. According to Slaughter:

> Societal leaders see higher education as generating and nurturing high technology. In turn, they see "high tech" as a way of freeing society from the economic morass in which it is presently mired. High technology is presented as a way of moving beyond job loss and plant closing, structural unemployment, a decaying industrial infrastructure, a fragile ecology all the while improving America's position in the national defense. However, public and private sector leaders concerned with education warn that this future cannot be reached without sacrifice. (Slaughter 1985, p 14)

Freeing society from the miseries of "job loss, plant closing, structural unemployment, a decaying industrial infrastructure, and a fragile ecology" seems as pertinent today as it was in 1985 when Slaughter conducted her research. Yet, as she also notes the expectations of university managers may have been based more on their own perceptions of what the most likely source of increased funding would be rather than on a realistic assessment of resource possibilities. In the end such expectations for faculty may simply have resulted in greater managerial control of the university. The real effect of the actual sidetracking of time and devotion for teaching and basic research has been labelled *commitment conflict*. Corporate managers have intensified faculty member's commitment conflict over the last 40 years by increasing funding for research while simultaneously reducing expenditures for teaching.

In several ways the public good has been affected by these changes. First, the employment of growing numbers of part-timers in the form of contingent labor, and teaching assistants hired on short term or at-will contracts as a flexible and easily disposable low-cost labor force has resulted in less student advising, limited student-faculty contact, decreased involvement with colleagues and in campus governance. As close interaction and contact between the student and the teacher is a crucial predictor of learning among students diminishing the contact has not served the students well. On top of this Henry Giroux (1999) comments that through part-time hiring a permanent, exploited and demoralized underclass of professional workers has been created.

Second, Slaughter (1993) argues that the growth in market-related fields has been detrimental to the social sciences and the humanities as these fields typically enroll larger numbers of women and students of color. Consequently, these groups have been affected disproportionately by reassigning faculty. In addition the change in the composition of faculty and the turn away from the social sciences and the humanities has been damaging for the role faculty in these fields has traditionally played in educating an enlightened citizenry, its political leaders, and in serving as the conscience and a critic of society. Instead there has been a general tendency that faculty in the social sciences and the humanities engage in developing consulting practices for corporations and industry. Moreover rather than focusing on teaching as a way to contribute to the economic goals of higher education, some leaders have instead chosen to pursue corporate partnerships and research alliances with other institutions.

Third, Gary Rhoades in his 1998 book *Managed Professionals: Unionized Faculty and Restructuring Academic Labor,* has shown how processes of deprofessionalization in tandem with a new managerial curriculum development strategy have resulted in a situation in which existing full-time faculty has lost control over the curriculum. Rhoades articulates faculty's uneasiness as follow:

> The managerial strategy in the production politics of teaching and technology is to establish new processes of student production on the periphery of the organization over which they have greater control. This periphery, which is largely outside the purview of traditional professionals and faculty input, is currently a marginal means by which to deliver curriculum and generate credit hours. However, that marginal activity, like the number of part-time faculty, many of whom will staff such courses, is likely to become increasingly central in coming years. To the extent that the use of instructional technology does grow, and to the extent that the use of part-time and/or nonbargaining-unit faculty to staff such course delivery grows, the position of full-time, traditional faculty will become increasingly marginal. (Rhoades 1998, p. 207)

Fourth, stratification of higher education by income, race, and gender is detrimental to women and minorities with respect to entering faculty ranks. In engineering education for example 4-year engineering programs are dominated by economically privileged white, heterosexual males and may be a challenge not only to this particular program but to engineering education generally and to the present and future composition of faculty in engineering departments. Brian Yoder (2012, p. 1) notes that "of the bachelor's degrees in engineering awarded in 2011, 81.6 percent went to males, 66.6 percent to whites, 12.2 percent to Asian-Americans, 8.5 percent to Hispanics and 4.2 percent to African-Americans". The current profile of engineering students is therefore out of touch with the demographics of the U.S. as a whole.

Even with these costs to the public good regarding faculty commitment and disempowerment some benefits result from the changes as well. First, according to Kezar (2004) the field of computer science would have remained relatively small if curricular decisions had been left in the hands of faculty, yet as new fields of courses and new models of delivery were requested by student the growth potential of computer science came to fruition. Second, some claim that students, parents, and community interests would not have been well served, and neither would the public good, had not changes in the faculty role been made. Slaughter and Leslie (2000) for example assert that "the idea of student as consumer has many merits because it gives the students some leverage over faculty" (Slaughter and Leslie 2000, p. 155).

12.4.4 Vocational Drift of Curriculum and Weakened Teaching

Mark C. Ebersole (1979) has pointed to the fact that utilitarianism has always been the distinctive motif of American higher education. Ebesole puts it this way: "as the specific practical interests and needs of society have altered, so have the programs of the colleges and universities reflected these changes" (ibid, p. 5). As higher education has now become an integral part of the American innovation system with the purpose of strengthening the nation's global competitiveness an increasingly vocationalized curriculum has emerged (Giroux 1999; Slaughter 1993). In examining state and institutional decision making patterns Gumport (1993, 2000) and Slaughter (1993) have found a national pattern of allocating significantly more resources for business and engineering at the expense of humanities/classics, fine arts, education, and foreign languages. In a similar vein Newfield (2010) has exposed the paradoxical effects of the American funding model in support of Gumport's and Slaughter's arguments.

According to Newfield (2008, 2010) funding that comes from state appropriations and student tuition is generally based on course enrollments and targeted for teaching. Taxpayers and students above all pay for undergraduate teaching. The workload related to teaching normally determines the amount of public money available for public universities through state appropriations. The teaching workload of departments in turn is defined as proportions of overall campus or system enrollments. Teaching workload money is used to pay the direct cost of teaching such as faculty and staff salaries as well as indirect costs related to buildings and construction, equipment, administration, course materials, and utility costs which are part of the teaching enterprise. As a result the humanities and social sciences are major donors to science and engineering budgets. Moreover students in these fields receive a cheap education, one in which they get back less in terms of fees than they put in. This means that Humanities and social sciences are being underdeveloped relative to their social and even their financial capacity.

Schultz observes that other universities and colleges earned their major revenues from programs in professional schools. Here programs in public and business administration, law, and MBA programs that rapidly multiplied were the real cash cows of the universities. Income streams from these programs were then used to finance the rest of the university. These programs were sold to applicants "with the claim that the high tuition would be more than offset by future earnings" (ibid., p. 2). Moreover these programs relied on attracting foreign student, returning baby boomers in need of additional credentials, and recent graduates "seeking professional degrees as a shortcut to professional advancement" (ibid., p. 2).

With respect to teaching the strong focus on research has led to a neglect of undergraduate education. Yet, somewhat paradoxically due to the American Funding Model revenues from undergraduate tuition and fees have been a major source of financial support in making the pursuit of research prestige possible. Through step raises in tuition undergraduate students have paid for the increase in research expenses related to "salary raises for star professors and lesser research luminaries, as well as for equipment and other amenities to help academic departments try to move upward in national rankings" (Sperber 2000, p. 93). These handsomely paid star professors help boost the prestige and research output of would-be public research universities until they get a better paid position in another university. They are therefore among the winners in the prestige race.

Concerning tuition and fees, Blumenstyk (2015) reports that between 1985 and 2012 the price of being enrolled in college rose by 538%[2] (whether public, private, or an average of both is not specified). Blumenstyk's figures do not specify the increase in tuition and fees for public universities but provide a general sense of the magnitude of increases during the period. Data for public universities can be found elsewhere[3] but for a shorter period of time. For public universities the average increase in tuition and fees from 1995 to 2015 was 179%. If the raise in tuition and fees is split between out-of-state students and in-state students the figures are 226% for out-of-state students in public universities with an average of $3506 in 2015, and 296% for in-state students at public universities with an average of $1431.

Moreover as the enrollment economy is depending on numbers too many students have been accepted who were not properly prepared or have been accepted with lacking capabilities. Among these are great numbers of athletic scholarship students. Furthermore as budgets became more stringent, administrators realized that the course load for research faculty could be lowered while a simultaneous increase in income from teaching could be achieved. This could happen by assigning a professor one large lecture class of for example 300 undergraduates. The calculation behind this example was simple:

> According to standard accounting practices within higher education, universities calculated that, based on faculty salary, it cost them $15,000 or more per class taught by a full-time professor; therefore, if student paid $250 a credit hour, thus $750 a course, three hundred undergraduates in a class generated $225,000, and the university started this lecture course $210,000 ahead. After factoring in other expenses, say, $10,000 to pay five teaching assistants ($2,000 each) for their work in the course, and about 2,000 for the maintenance and utilities on the lecture hall and section rooms, and $2,500 for various miscellaneous and hidden costs, the bottom line ….. was $195,000 profit. (Sperber 2000, p. 86)

To the extent that this is normal practice it means that undergraduate students do not actually get what they suppose they are paying for. An aggravating fact is that the myth prevails that high tuition equals quality. It should therefore come as no surprise that undergraduate students under these conditions have been the great losers in the corporatized public university. Sperber (2000) has argued in favor of four radical proposals for remedial action. First, large, public universities must enroll fewer students who are really qualified and who should be offered a quality undergraduate education. Second faculty in these institutions should be employed primarily for teaching undergraduates, and only secondarily for research of which some parts should be devoted to pedagogy. Third, instead of using teaching methods that turn undergraduates unto passive receptacles an interactive inquiry based pedagogy should be used. Fourth, the requirement for all undergraduates to before receiving

[2] Further specification of changes over time in tuition and relevant comparisons can be found in Blumen- styk (2015, pp. 52–54).

[3] www.usnews.com/education/best-colleges/paying-for-college/articles/2015/07/29/

their bachelor's degree should be the attainment of a minimum score on the Graduate Record Exam.

Vocational drift of the curriculum and the downgrading of teaching affect the social good in a number of ways. First, quality education is more than training for a job and a career. The purpose of quality education is also under intellectual guidance of the teacher to foster independent habits of mind and a spirit of enquiry free from the bias and prejudices of the moment, thereby contributing to educate an enlightened citizenry and its intellectual leaders. It is also the purpose of such education to expose the students to a variety of disciplines. This has traditionally been the role of the humanities and the non-applied social science fields as well as holistic and critical thinking pedagogies, and these have been key elements in higher education's contribution to the public good. Vocational curricula are less likely to offer such broadening learning experiences. The essence of quality education and its present predicament have been brilliantly expressed by Harry R. Lewis, a former dean of Harvard College. In his 2006 book *Excellence without a Soul: How a great University forgot Education,* he argues:

> In short, universities have forgotten their larger educational role for college students. They succeed, better than ever, as creators and repositories of knowledge. But they have forgotten that the fundamental job of undergraduate education is to turn eighteen- and nineteen-year-olds into twenty-one- and twenty-two-year-olds, to help them grow up, to leave college as better human beings. So totally has the goal of excellence overshadowed universities' educational role that they have forgotten that the two need not be in conflict. Lip service to education remains…..Rarely will you hear more than bromides about personal strength, integrity, kindness, cooperation, compassion…..The greater the university, the more intent it is on competitive success in the marketplace of faculty, students, and research money. (Lewis 2006, p. xii)

Second, as noted by Sperber (2000) in the quotation given above, quality mass higher education at the undergraduate level cannot be promoted through lecture-driven pedagogies in large lecture halls. In so doing learning suffers. Learning through problem and project based pedagogy is a better way to supply quality mass undergraduate education still in a cost-effective way. In the same vein Duderstadt (2004) has argued that it has been realized that learning does not take place primarily through study and contemplation but through learning in the research mode that is through active discovery and application of knowledge. Third, the preservation of knowledge will suffer when certain fields are underfunded or closed. Fourth, the advancement of knowledge will suffer if not a broad spectrum of disciplines can be brought to bear on any problem.

Benefits to the public good with regard to an increasingly vocationalized curriculum should also be mentioned. First, and most importantly changes in the curriculum in terms of growth of vocational fields and distance learning has enabled greater access to higher education. This change has been favorable for under-served parts of the population. Second, this would not have been possible, had administrators not responded to student demands in more popular fields. A paradoxical effect of the more vocationally oriented curriculum delivered through distance learning has been that an enrollment shift to for-profit colleges from public colleges among low-income white students and poor students from other racial and ethnic groups began in 2000 (Blumenstyk 2015). According to the view of critics reported by Blumenstyk "the concentration of low-income and minority students at for-profit colleges is a sign that the industry has been successful in aiming its aggressive, and in some cases predatory, recruiting tactics at students with the least information about how best to select a college and the fewest resources to pay for it (ibid. p. 33).

12.5 Conclusion

The purpose of this chapter has been to review the relevant literatures and hence to examine how the corporatized public university came about, to compose an ideal type of its distinctive features, and to consider costs and benefits to the collective or public good of commercializing teaching, research and service. The focus has been on changes that have taken place in higher education in the United States over the last four decades. The analysis has shown that the corporatization of the public research university associated with the industrial model of higher education is pervasive.

As noted by Alison Palmadessa (2015) in the twenty-first century the public university has been called upon to serve the public "by educating its citizens for service and share new knowledge gained for the benefit of all, as well as assist the nation's economy by producing an educated workforce and commodifiable knowledge" (Palmadessa 2015, p. 46). Patricia J. Gumport (2002) has conceptualized this dual role as a tension between two dominant institutional logics or models of higher education in university restructuring, namely those of the university as a social institution and the university as an industry. The dual role of the public research university therefore challenges the American university of the past. Palmadessa (ibid.) argues that the new role of public research universities, namely to support the economy, "is a challenge to the traditional social purpose of the university" (ibid, p. 46). Both Kezar (2004) and Palmadessa (2015) therefore argue in favor of renegotiating the "social charter" between the university and the public in order to achieve a blending of the traditional model and the industrial model of higher education.

Considering costs and benefits to the public good as defined in the neoliberal charter the chapter has shown that the costs related to corporatization of the public university outnumber and outweigh the benefits. Exploitative practices have been seen both with respect to students, their parents, faculty, and within teaching and research. In addition to the commercial exploitation of research which has led to new inventions, medicines and other outcome covered by patent laws, Ellen Boesenberg (2015) has shown that the commodification of knowledge opens another avenue for exploitation, namely the selling of knowledge produced for pedagogical purposes. She notes that also what has come to be called "content knowledge" – a type of intellectual property – in the form of curricula, lecture notes, and even student notes, has been commodified (ibid., p. 22). She also notes that teaching as a holistic activity is now threatened by radical changes in the conception of teaching in higher education. In the words of Boesenberg the industrial model of higher of higher education implies that:

> In conjunction with the use of contingent labor, distance learning programs, course management systems…and *digital courseware* the outsourcing of the teaching function's transformation is now absolute with the commodification of the curricula, syllabi, lecture notes, and student notes. One of the techniques that helps make the outsourcing of teaching possible is called "course redesign". In effect course redesign bypasses a major aspect of the teaching function through the use of digital courseware that eliminates the need for a professor to present a live lecture or even to be present with the students at all. (Boesenberg 2015, p. 23)

For a renegotiation of the "social charter" between the public and the university to succeed aimed at blending the traditional model and the industrial model of public higher education different from that of the corporatized university, students and faculty, will minimally be required to develop ideas with respect to the funding of the envisioned renegotiated charter between the university and the public and to build broad public support for this vision. As Slaughter and Leslie (2000, p. 155) argue "simply expecting the state to supply more money is unrealistic".

References

Aronowitz, S. (2000). *The knowledge factory: Dismantling the corporate university and creating true higher learning*. Boston: Beacon Press.

Ball, S. T. (2003). The teacher's soul and the terrors of performativity. *Journal of Education Policy, 18*(2), 215–228.

Barrow, C. W. (1996). The strategy of selective excellence: Redesigning higher education for global competition in a post-industrial society. *Higher Education, 4*, 447–469.

Barrow, C. W. (2010). The rationality crisis in U.S. higher education. *New Political Science, 32*(3), 317–344.

Blumenstyk, G. (2015). *American higher education in crisis? What everyone needs to know*. Oxford: Oxford University Press.

Boesenberg, E. (2015). Survival in the new corporatized academy: Resisting the privatization of higher education. *Work, 25*, 16–36.

Bok, D. (2003). *Universities in the marketplace: The commercialization of higher education*. New Jersey: Princeton University Press.

Bush, V. (1945). *Science, the endless frontier; a report to the president on a program for postwar scientific research.* Reprinted July 1960. Filiquarian Publishing, LLC./Qontro. Printed in Great Britain by Amazon.

Carlin, J. F. (1999). Restoring sanity to an academic world gone mad. *The Cronicle of Higher Education, 46*(11).

Collins, R. (2002). Credential inflation and the future of universities. In S. Brint (Ed.), *The future of the city of intellect: The changing American university*. Stanford: Stanford University Press.

Deem, R. (2001). New managerialism, academic capitalism and entrepreneurialism in universities: Is the local dimension still important? *Comparative Education, 37*(1), 7–20.

Duderstadt, J. J. (2004). The changing nature of research and the future of the university. In L. L. Weber & J. J. Duderstadt (Eds.), *Reinventing the Research University*. London: Economica.

Ebersole, M. C. (1979). The distinctive motif of American higher education. *The Journal of Education., 161*(4), 5–19.

Furedi, F. (2011). Introduction to the marketization of higher education and the student as consumer. In M. Molesworth, R. Scullion, & E. Nixon (Eds.), *The marketization of higher education and the student as consumer*. London: Routledge.

Giroux, H. A. (1999). Vocationalizing higher education: Schooling and the politics of corporate culture. *College Literature, 26*(3), 147–161.

Giroux, H. A. (2014). *Neoliberalism's war on higher education*. Chicago: Heymarket Books.

Gumport, P. J. (1993). The contested terrain of academic program reduction. *Journal of Higher Education, 64*(3), 283–311.

Gumport, P. J. (2000). Restructuring: Organisational change and institutional imperatives. *Higher Education, 39*(1), 67–91.

Gumport, P. J. (2002). Universities and knowledge: Restructuring of the city of intellect. In S. Brint (Ed.), *The future of the city of intellect: The changing American university*. Stanford: Stanford University Press.

Gumport, P. J., & Pusser, B. (1995). A case of bureaucratic accretion: Context and consequences. *The Journal of Higher Education, 66*(5), 493–520.

Kauppinen, I., Coco, L., Choi, H., & Brajkovic, L. (2016). Blurring boundaries and borders: Interlocks between AAU institutions and transnational corporations. In S. Slaughter & B. J. Taylor (Eds.), *Higher education, stratification, and workforce development: Competitive advantage in Europe, the U.S. and Canada*, *Springer, Higher Education Dynamics, 45*. Dordrecth: Springer.

Kezar, A. (2004). Obtaining integrity? Reviewing and examining the charter between higher education and society. *The Review of Higher Education, 27*(4), 429–459.

Labaree, D. F. (1997). Public goods, private goods: The American struggle over educational goals. *American Educational Research Journal, 34*(1), 39–81.

Lave, R., Mirowski, P., & Randalls, S. (2010). Introduction: STS and neoliberal science. *Social Studies of Science, 40*(5), 659–675.

Lewis, H. R. (2006). *Excellence without a soul: How a great university forgot education*. New York: PublicAffairs, A Member of the Perseus Book Group.

Minsky, L. (2000). Dead souls: The aftermath of Bayh-Dole. In G. D. White & F. Hauck (Eds.), *Campus Inc.: Corporate power in the ivory tower*. New York: Prometheus Books.

Newfield, C. (2003). *Ivy and industry: Business and the making of the American university, 1880–1980*. London: Duke University Press.

Newfield, C. (2004). Jurassic U: The state of university-industry relations. *Social Text 79, 22*(2), 37–66.

Newfield, C. (2008). *Unmaking the public university: The forty-year assault on the middle class*. Cambridge, MA: Harward University Press.

Newfield, C. (2010). The end of the American funding model: What comes next? *American Literature, 82*(3), 611–635.

Noble, D. (2002). *Digital diploma mills: The automation of higher education*. New York: Monthly Review Press.

Palmadessa, A. (2015). Academic capitalism and the social charter between the university and the public. *Higher Education in Review, 11*, 45–61.

Press, E., & Washburn, J. (2000). The kept university. *The Atlantic,* March 2000 Issue.

Readings, B. (1996). *The university in ruins*. Cambridge, MA: Harvard University Press.

Rhoades, G. (1998). *Managed professionals: Unionized faculty and restructuring academic labor*. New York: State University of New York Press.

Rhoades, G. (2013). Disruptive innovations for adjunct faculty: Common sense for the common good. *Thought and Action, 71*, 71–86.

Sauntson, H., & Morrish, L. (2011). Vision, values and international excellence: The “products” that university mission statements sell to students. In M. Molesworth, R. Scullion, & E. Nixon (Eds.), *The marketization of higher education and the student as consumer*. London: Routledge.
Schultz, D. (2015). The rise and coming demise of the Corporate University. *Academe, 101*(5), 21–23.
Slaughter, S. A. (1985). From serving students to serving the economy: Changing expectations of faculty role and performance. *Higher Education, 14*, 41–56.
Slaughter, S. (1988). Academic freedom and the state: Reflections on the uses of knowledge. *The Journal of Higher Education, 59*(3), 241–262.
Slaughter, S. A. (1993). Retrenchment in the 1980s: The politics of prestige and gender. *Journal of Higher Education, 64*(3), 250–282.
Slaughter, S. A., & Leslie, L. L. (1997). *Academic capitalism: Politics, policies, and the entrepreneurial university*. Baltimore: The Johns Hopkins University Press.
Slaughter, S. A., & Leslie, L. L. (2000). Professors going pro: The commercialization of teaching, research, and service. In G. D. White & F. Hauck (Eds.), *Campus Inc.: Corporate power in the ivory tower*. New York: Prometheus Books.
Slaughter, S. A., & Rhoades, G. (1996). The emergence of a competitiveness research and development policy coalition and the commercialization of academic science and technology. *Science, Technology, & Human Values, 21*(3), 303–339.
Slaughter, S. A., & Rhoades, G. (2004). *Academic capitalism and the new economy: Markets, state, and higher education*. Baltimore: The Johns Hopkins University Press.
Soley, L. C. (1995). *Leasing the ivory tower:The corporate takeover of academia*. Boston: South End Press.
Sperber, M. (2000). *Beer and circus: How big-time college sports is crippling undergraduate education*. New York: Henry Holt and Company, LLC.
Steck, H. (2003). Corporatization of the university: Seeking conceptual clarity. *The Annals of the American Academy of Political and Social Science, 525*, 66–83.
Steck, H., & Zweig, M. (2000). Take back the university: Only unions can save academic life. In G. D. White & F. Hauck (Eds.), *Campus Inc.: Corporate power in the ivory tower*. New York: Prometheus Books.
Steger, M. B., & Roy, R. K. (2010). *Neoliberalism: A very short introduction*. Oxford: Oxford University Press.
Szelényi, K., & Goldberg, R. A. (2011). Commercial funding in academe: Examining the correlates of faculty’s use of industrial and business funding for academic work. *The Journal of Higher Education, 82*(6), 775–802.
Valsan, G., & Sproul, R. (2008). The invisible hand behind student evaluation of teaching: The rise of a new managerial elite in the governance of higher education. *Journal of Economic Issues, 42*(4), 939–958.
Washburn, J. (2005). *University Inc,:The corporate corruption of higher education*. New York: Basic Books.
Yoder, B.L. (2012). Engineering by the numbers. *American Society for Engineering Education.* Retrievedfrom:http://www.asee.org/paperand-publications/publications/college-profiles/2011-profile-engineering-statistics.pdf
Zemsky, R., & Duderstadt, J. J. (2004). Reinventing the research university: An American perspective. In L. L. Weber & J. J. Duderstadt (Eds.), *Reinventing the Research University*. London: Economica.

Steen Hyldgaard Christensen MA in Danish Language and Literature and the History of Ideas from Aarhus University, PhD in Engineering Education Research from Aalborg University. Until 2014 senior lecturer at Aarhus University. Since 2014 Adjunct associate professor at Aalborg University. He is lead editor and co-author of 6 edited volumes: *Profession, Culture, and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives* (Springer 2012), *International Perspectives on Engineering Education*: *Engineering Education and Practice in Context. Volume I* (Springer 2015), and *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context. Volume II* (Springer 2015). Besides he has co-authored *A Hybrid Imagination: Science and Technology in Cultural Perspective* (Morgan & Claypool Publishers 2011) together with Andrew Jamison and Lars Botin. In addition he has published a number of articles on engineering epistemology, culture and higher education. Current research interest: Dynamics in higher education restructuring, Thorstein Veblen, and the tension between engineering and business.

Part III
The Practices of Business and Engineering

Chapter 13
Technology and the Practice of Engineering

Erik W. Aslaksen

Abstract The relationship between business and engineering is dominated by two features. One is the need for business to provide opportunities for generating a return on the increasing amount of capital resulting from the capitalist economic system. The other is that engineering, in the form of applying technology to meet expressed needs, automatically generates new technology, which presents business with new possibilities. It is this (vicious?) circle that determines the dynamics of the engineering-business nexus and is one of its core features. After first defining the various concepts involved in the form of a consistent practical ontology, this chapter examines the relationships between industry, society, and engineering, as a precursor to focusing on the relationship between engineering and technology in some detail. In particular, it is the dynamics of the relationship and the extent to which it is affected by the environment in which engineering is embedded – the engineering paradigm – that are often not appreciated. The conclusion is that engineering, as a profession, has not responded adequately to the changes in its environment over the last 50 years or so, and that the practice of engineering is due for a paradigm shift. This shift will have a significant effect on both the manner in which engineers are employed in industry and the education of engineers, and it is suggested that it is education that will have to take the lead in effecting the shift.

Keywords Engineering · Technology · Industry · Market · Business · Society · Paradigm

E. W. Aslaksen (✉)
Gumbooya Pty Ltd, 3 Gumbooya Street, Allambie Heights, NSW, Australia
e-mail: erik@gumbooya.com

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_13

13.1 Introduction

The engineering-business nexus involves six closely related concepts – engineering, technology, industry, market, business, and society – and to pursue the purpose of this chapter, which is to discuss the roles of technology and the practice of engineering in this context, it is beneficial to start by defining these concepts and their relationships in terms focused on our purpose. Starting with *society*, it shall be defined as a set of individuals, their organizational entities (educational, judicial, defense, etc.), and their artefacts (devices, equipment, technological systems, knowledge repositories, and built environment). A common definition of *business* is "the activity of buying and selling commodities, products, or services". Now, if every household in a society were completely self-sufficient, i.e. produced its own food, clothing, utensils, dwelling, etc., there would be nothing to buy or sell, and no business. Therefore, implicit in the definition is a division of labor and a corresponding *view* (in the sense of systems engineering) of society as a functional structure, a view originally developed by Emile Durkheim (1893). Under this perspective, business appears as the interaction that converts that structure into a system – the economy. Each structural component has a dual nature, as producer and as consumer, and we can then create a high-level view of the economy consisting of two interacting parts: *industry*, as the collection of all the producers, and the *market*, as the collection of all the consumers.

Definitions of engineering and technology were provided in an earlier fPET (forum on Philosophy, Engineering & Technology) presentation (Aslaksen 2012). Very briefly, they were that *technology* consists of a resource base (construction elements, tools, etc.) and a knowledge base (text books, publications, standards, heuristics, etc.); that *engineering* is the process of developing and applying this technology in order to meet needs expressed by groups or all of society; and that the practitioners of this process are the engineers. We also noted that "technology" is a highly context-dependent concept, and in the following we will show that the issues related to this context-dependency, as they arise in philosophy, in policy discussions about "science and technology", and in the mass media, play a significant role in the engineering-business nexus.

Industry forms the link between engineering and business, and Fig. 13.1 shows a highly simplified view of the relationships between the four entities – engineering,

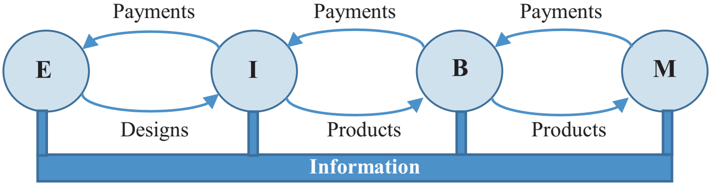

Fig. 13.1 Simplified relationships between the four entities: engineering (E), industry (I), business (B), and market (M). In this figure "designs" encompasses all the artefacts and services provided by engineering to industry, and "products" includes commodities and services

industry, business, and market. The main point of this illustration is to emphasize that, in addition to the obvious flows of products and funds, there is a significant interchange of information between all four entities. The relationship between engineering and industry is, as Fig. 13.1 indicates, a very direct one; to the extent that one might say that engineering is *embedded* in industry. The relationship between engineering and business is quite different; indirect as far as the flows of products and payments are concerned, but possibly quite direct as far as information goes.

Engineering and business are both situated within the framework of society. They are products of its history and subject to its laws and customs, and, as processes, interact with all the other entities in that framework. But we can also view the two of them from a narrowly focused perspective which highlights that they operate in quite different domains – engineering in the domain of creation bounded by rationality, continuity, and the laws of Nature; business in the domain of human desires, perceptions, and irrational behavior – and that the existence and success of each of them are closely linked. In that link technology plays a major role and, somewhat paradoxically, it is the context-dependency of the concept that enables it to play that role.

In the business domain, the use of "technology" is not sharply defined; on the contrary, it takes on a certain magic quality, representing a promise of overcoming the currently experienced limitations placed on us by our physical environment. It is used to express a general desirable quality arising from the previous successes associated with this concept, such as air transport, high speed rail, space flight, telecommunications, the Internet, computers, mobile phones, advances in medicine, new synthetic materials, and so on. In this domain, "an application of high technology", "based on a recent advance in technology", and similar phrases express the fact that for business "technology" is one of the parameters characterizing the salability of a product or service. A symbol of man's triumph over Nature as, indeed, is business itself.

In the engineering domain, technology is a resource; it is something that is used by engineering. The purpose of engineering is to meet needs expressed by society (or parts of society) by creating applications of technology, and so technology, while indispensable, is secondary to the core of engineering, which is the creative activity.

However different these two meanings of "technology" are, they are united in that each is essential to the success of the activities in its domain. For business, "technology" is a main driver of profitability and growth; for engineering it is the physical and intellectual foundation on which its existence is based. This Janus-nature of "technology" is the core of the engineering-business nexus, and we shall return to that in the third section of this chapter. But first it is useful and makes the chapter more self-contained to consider some fundamental aspects of engineering, based largely on some earlier work that will support the arguments in the third section.

13.2 Background Material

13.2.1 Technology in the Context of Engineering

In order to define "technology" and understand its role in the context of engineering, we recall briefly some of our work presented at fPET-2012 (Aslaksen 2012). Ontologically, engineering belongs in the upper level category of *processes*, and within this category we can distinguish a sub-category of *purposeful processes*; these are processes that have a purpose formulated by humans, as opposed to other processes, such as the change of seasons, erosion, and the processes taking place within stars, as well as the numerous processes carried out by all other organisms. The category of purposeful processes contains two sub-categories. One is what we shall call *realization processes,* i.e. processes that convert the results of intellectual work into *services* useful to society or to groups of society. The other sub-category is what we shall call *professional processes;* these are distinguished by the extent of the knowledge bases and the intellectual effort required by the practitioners to acquire and apply this knowledge; in effect, by the investment in education and experience. This sub-category includes the class of engineering processes, but also a wide range of processes outside of engineering, such as medicine, dentistry, architecture, and economics. Professional processes are further distinguished by the fact that each one is related to and, to some extent, embedded in, a corresponding realization process. Law is related to law enforcement processes (without which law would be without value), medicine is related to health care processes, and so forth. Engineering is related to *industrial processes*, which are processes that involve a conversion of natural resources in order to fulfil their purposes, but the distinguishing feature of engineering is that *every instance of the engineering process is embedded in an instance of the industrial process* (this is also true of architecture, which is embedded in a subset of the industrial processes: the building industry). This means that we cannot consider any effect of engineering on society without considering the associated industrial process, which is what we reflected in Fig. 13.1. Engineering without industry is just like dreaming. The foregoing framework is illustrated in Fig. 13.2.

The *process of engineering* (or simply *engineering*) is defined within the class of professional processes by its knowledge and resource bases, and the combination of these two bases is what we define as *technology*. The resource base consists of the millions of standard construction elements, ranging from reinforcing steel bars to microprocessors, that engineers and the technical workforce can draw on in executing projects, as well as the facilities within industry for fabricating and constructing plant. The knowledge base is comprised of textbooks, standards, published papers, operating manuals for tools and instruments, etc., and spans a continuum from advanced research to Tables for everyday use. It also comprises the tacit knowledge embodied in individual engineers, generated through their personal professional experience. Both of these bases are dynamic: new construction elements are continually being added and older elements are being phased out; new knowledge is

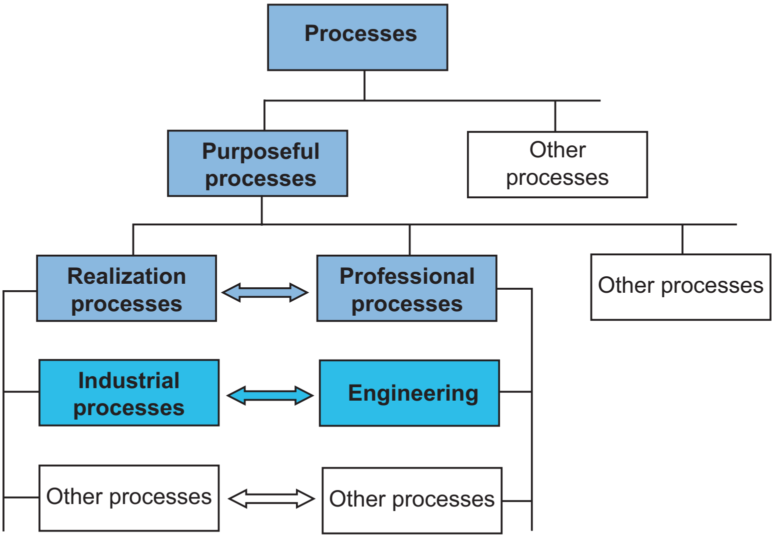

Fig. 13.2 The framework of processes within which engineering is defined. (Aslaksen 2014)

being generated through research and experience, and what was advanced knowledge yesterday is tomorrow's accepted practice, often embodied in standards.

A result of the continuous transformation of technology, as well as the current exponential increase in volume, is that, in the sense of understanding, maintaining, and being competent in using, various actors relate to different parts of technology, as was discussed in *The Future of Engineering* (Aslaksen 2015a) and illustrated in Fig. 13.3. The *technical workforce* includes technologists, technicians, drafters, and trades persons, i.e. all people who, in addition to engineers, require access to the combined knowledge and resource bases, that is, technology. This structuring is defined formally, and to a large extent also in practice, by education and training, but experience and individual interest and aptitude can result in a significant blurring of the boundaries. Initial results of a study of how this structure is perceived by faculty and students is contained in *Examining the Identities of Engineers, Technologists and Engineering Technologists* (Murphy et al. 2012). At this stage, we shall define an engineer as someone with a degree from an accredited 4-year university course and meeting certain requirements for Continuing Professional Education (CPE). Engineers are the practitioners of the professional process of engineering, and the engineering disciplines, such as civil, chemical, electrical, and mechanical engineering, are distinguished by the subdivision of the resource and knowledge bases reflected in their education.

The identification of the resource and knowledge bases as constituting "technology" is a deviation from the use of "technology" by philosophers and sociologists, who use it in a much more encompassing manner, such as "the production and use of artefacts". And many publications on the philosophy of technology make no mention of engineering at all. However, while much of what philosophers say about

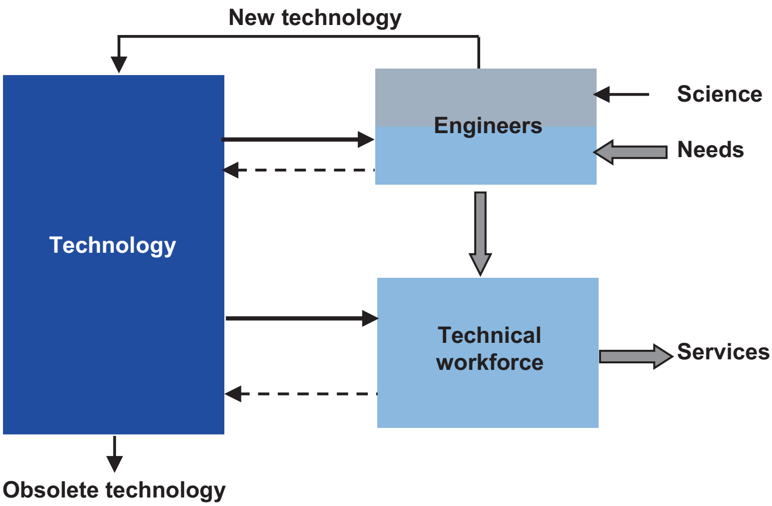

Fig. 13.3 The interaction with technology by engineers and the technical workforce. The dotted arrows indicate that all engineering projects provide some input to technology in the form of experience, and the subdivision of the engineers illustrates the two types of engineering projects. (Aslaksen 2015a, p. 160)

technology can be reflected onto engineering, it is important to keep the distinction in mind; in particular, the above definition of technology does not include any activity. Whereas philosophers see technology as an activity (or at least including activities), no engineer would speak of "doing technology". Engineers apply technology in order to meet society's requirements, and students study technology in order to become engineers.

13.2.2 The Practice of Engineering

Having now defined the use of "technology" within engineering, we consider the activity of engineering itself. That activity consists basically of individual *projects*, each on an instance of the engineering process. Each project has a defined purpose, and this allows us to distinguish two groups of engineering projects according to the nature of their purposes:

- Projects that utilize the existing resource and knowledge bases to meet a *need* expressed by all or a part of society; and
- Projects that increase the resource and knowledge bases.

In other words, projects in the first group *apply* technology in order to meet requirements imposed by entities or people who are generally not engineers, and it is these stakeholders that are the judges of the project success; whereas projects in the second group *develop* technology, often using that part of the knowledge base that is provided by science, but sometimes also based on heuristics or arising from trial-and-error, and their success is judged generally by other engineers. We shall call these two groups of engineering projects *application projects* and *development projects*, respectively. There is not a sharp boundary between these two groups, and there will be many projects that contain sub-projects of both types. In any case, every application project also leads to an increase in technology, if by nothing else than by simply acting as an example for later projects, as is indicated in Fig. 13.3. The usefulness of this grouping and the distinctiveness of the two groups were discussed in *An Engineer's Approach to the Philosophy of Engineering* (Aslaksen 2012); in particular, as the group of application projects is largely greater in number and direct importance to society than the development group, it allows us, by focusing hereafter exclusively on the former group, to make general statements.

At this point we need to eliminate a semantic issue: it has been commonplace to refer to the whole process of providing a service that meets an expressed need as "the process of engineering"; both because engineers are, to varying degrees, involved throughout the process, and because the general public does not see inside the process and so uses convenient labels like "industry" and "engineering" without reflecting on their precise meaning. This common usage was also adopted in a previous publication by the author of this chapter (Aslaksen 1996), but needs to be made more specific in the current context for two reasons: first, because we are now identifying business as a separate process whereas, when industry is considered as one of the segments of the economy, business (i.e. buying and selling) is included as its commercial (or non-technical) aspect, just as it is in other segments, such as education and health care. Secondly, because we are concerned with the relationship between engineering and business, as opposed to the role of engineers in the wider context of the interface with the market or, more generally, society. That is why we have identified engineering as a separate process, albeit embedded in an industrial process; and in order to avoid misunderstandings, we should now refer to the technical content of the process of providing a service as the *industrial process*, in accordance with the taxonomy shown in Fig. 13.2.

This is illustrated in Fig. 13.4, where engineers perform the process of engineering, which is part of the industrial process performed by the technical workforce,

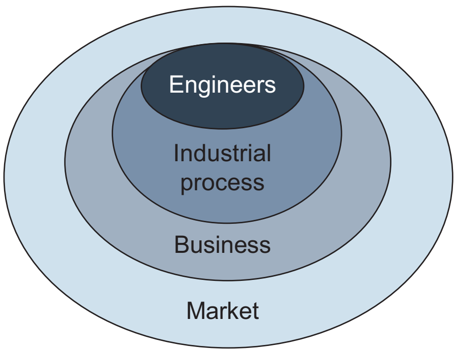

Fig. 13.4 The relationships between engineers, the industrial process, business, and the market (or society). It also illustrates that the direct interface between engineers and business is currently quite limited

and which interacts with the market through business. All three entities have an interface to the market, but it is dominated by that of business. What society experiences as “technology” is largely determined by business.

13.2.3 Engineering and Science

Engineering and science have a particular relationship. On the one hand, they are closely related, in that science provides much of the theoretical foundation for engineering, and in that engineering provides much of the equipment and facilities required by science. On the other hand, they are very different, in that, at least for much of its history, science was about expanding our understanding of Nature, its laws and processes, and that the criteria for judging its worth were novelty and truth, with little concern for any practical outcomes; whereas engineering has always been about usefulness and a return on investment. The judges of science are, to a large extent, the scientists themselves, whereas the judges of engineering are the users.

But perhaps the greatest difference is in how the two are viewed by the public and the public’s understanding of what they entail, and the following example may illustrate this. The transistor effect, that is, the ability to control a large flow of current through a solid by means of a small current, was discovered by three scientists, Shockley, Bardeen, and Brattain, for which they received public renown and a Nobel Prize. However, the hundreds of engineers that overcame all the practical problems in vacuum technology, lithography, clean room technology, doping technology, micro-positioning, bonding, and so on, in order to actually bring a usable and cost-effective device onto the market, remain completely unknown to the public. Moreover there is no understanding of the relative amount of work involved; somehow, the public (and politicians) seem to believe that science leads directly to products.

Engineering is a significant component of the activities taking place in society. This is obvious by just taking a look at the objects surrounding us; almost all of them owe their existence to engineering to some degree. Consequently, one could expect that engineering would have a significant impact on the direction in which society is developing, but do engineers have a significant impact, or are they just the ones turning the crank? It is astonishing how little attention this question has received, and the reason for it can be summarized by saying that engineers are practically invisible, as far as society is concerned. This is evidenced by the observation that there has been quite some interest in what is characterized as Science, Technology, and Society (STS), or Science and Technology studies; but that the overwhelming part of the literature on this subject makes no mention of engineers at all, despite the fact that technology is created largely by engineers, whereas scientists provide mainly the theoretical foundation. Science is fairly well established in the public mind, whereas most people have no idea what engineering entails, and its achievements are rarely reported. In Australia this was exemplified recently with the tabling of two statements on “Science and Innovation” in the House of

Representatives (Macfarlane 2015), in which engineering was almost ignored; it also missed the facts that technology is created mainly by engineers, that innovation, i.e. bringing a novel and profitable product to the market, involves only a relatively small scientific effort, and that its success depends much more on the engineers involved than on scientists. In this regard, recommended reading for those interested in innovation policy is the book "*The Soul of a New Machine*" by Tracy Kidder (1981).

We also note that the majority of the new technology is developed as part of application projects and arises out of the quest to find better, more cost-effective solutions to given requirements. Projects dedicated to developing new technology, often inspired by new scientific results, and without any commercial application in mind, are relatively rare, and found mostly in universities and their associated research institutions.

13.3 Engineering, Technology, and Business

13.3.1 The Engineering-Business Nexus: A Relationship in Transition

The image presented in Fig. 13.1 shows two distinct interfaces between engineering and business: an indirect one, via industry, and a direct one through information interchange. The first one is the classical interface, based mainly on product design for predetermined requirements, and it is probably fair to say that until about 1980 this interface was so dominant that engineering appeared *embedded* in industry. This lack of what we might call "social independence", and its effect on the nature of engineering were noted by numerous authors, such as Thorstein Veblen (1921), Edwin Layton (1971), David F. Noble (1977), Langdon Winner (1995), Byron Newberry (2007), and Erik Aslaksen (2014). The issue addressed in these works is the insensitivity, or indeed ignorance, of engineers with regard to the concerns of society, arising from their embedment in industry. For the purpose of this chapter, we need to recognize that we are mainly concerned with a limited aspect of this issue; rather than the interaction with society in general, we are focusing on the interaction with society through the "filter" of the business process. That is, with society limited to the market aspect, through the second indirect interface in Fig. 13.1.

Here we should make a brief comment on Fig. 13.1. The four separate entities are functional entities, their physical realization may or may not be separate. Engineering may be provided by a separate engineering firm, or may be a department within an industrial organization. Similarly, the business function may be provided by a separate company, such as a trading company or a wholesaler, but may also be provided by a department of an industrial organization. While these differences may be significant for such activities as human resource management, financing, accounting, and the like, they will not influence our investigation which is concerned only with the entities as high-level functions. In particular, as already noted, the business function is seen as separate from the product creation function, or what we earlier identified as the industrial process.

From a narrow economic point of view, engineering and business are tied together in a feed-back loop. In looking for opportunities to invest capital and generate a return, business finds needs that are either explicitly expressed by society or perceived by business as latent needs that it believes could be met by applying technology. Engineering creates the required applications, and in so doing, generates new technology through the continuous improvement process that is part of every engineering project. These applications of technology generate further capital in the form of the return on the investment; business looks for new opportunities using the new technology, and so on. In this loop, the interface between engineering and business is technology, but the drive is the need to generate a return on the exponentially increasing amount of capital. The implications of this structure for the evolution of society is discussed in some detail in *A Story of Us: Evolution and the Individual* (Aslaksen 2015b); for our purpose in this chapter, it is only important to recognize the strength and centrality of this economic relationship in which engineering and business are embraced.

However, aside from the economic aspects, the relationship has undergone some significant changes. In the early days of engineering as a recognized profession, say, until 1900, engineers and business people had close personal relationships, and leading engineers were often also leading business men. Then, with the rise of mass production and the importance of promoting consumption, there was an increasing tendency to isolate engineering from the business process, and engineers became technical problem solvers and "backroom boys" in an overall stove-piped process, with "over the wall" interaction between functions. Since that time, there has been a growing realization of the drawbacks of this type of organization; not only because of its inefficiency through misunderstanding and lost information, but increasingly because non-economic issues, such as ethical, sustainability, and environmental issues, became important and needed consultation between business and engineering.

One manifestation of this is the number of combined engineering/business degrees being offered, as well as the inclusion of business subjects in engineering curricula. However, while these are steps in the right direction, they are primarily directed at the symptoms, or external manifestations, of the problem rather than at its core, which is the lack of a common intellectual perception of the object of cooperation. This is quite visible in the early stage of a project involving technology in some form, i.e. an engineering project. In the author's experience, the inception of a project is in essence performed exclusively either by business people or by engineers; any cooperation occurs only when discipline-specific skills are required to address well-defined problems or tasks. As a metaphor, when an engineer and a business person each look at different sides of a coin, what each one sees is a picture containing a certain message or amount of information, without realizing that they are two sides of the same coin. But even worse, they do not realize that there is such a thing as a coin. What is missing from the engineering-business nexus is the realization that, at the highest level of abstraction, there is no difference between engineering and business, nor is there a clear understanding of the nature of the common entity representing a project at this level. A proposal for an approach to this problem, developed over more than two decades, is detailed in *The Engineering Paradigm* (Aslaksen 2013), albeit in a language more familiar to engineers than to business people.

13.3.2 Business and Technology

The involvement of technology in business is twofold, and in order to discuss this, it is of use to consider that the *business process* consists of three groups of processes: management processes, operational processes, and supporting processes. In all three of them, a whole host of technical applications are used as tools to improve both their efficiency and their effectiveness. In the first group we find Business Process Management (BPM) software; the second group includes a diverse collection of information-processing applications supporting such activities as market analysis and supply chain optimization; and in the third group are widely used applications for such activities as HR management and accounting. These applications are not what we are focusing on as the technology involved in the engineering-business nexus; as was noted in the Introduction, that is the technology reflected in the products being bought and sold. It is located within the group of operational processes, and there are several aspects to this role of technology.

Within business, technology emerges as an expectation for the realization, at least in part, of a perceived business opportunity. A business opportunity is an opportunity for the business to do something – basically a process to deliver a service (which may involve supplying a product) to a market segment – and as this process is defined and described, parts of it are allocated to being provided by technological applications. Here technology is used purely in the sense of *what* it has to achieve within the business process, not in the sense it is used within engineering as a resource for *how* to achieve it. This requires now, on the part of business, a translation from the language of business (market characteristics, branding, competitive advantage, etc.) to the common language.

But, as with engineering, there is also the internal use of technology within the business process. The attributes of the technology components of the service delivery become integrated into the marketing strategy, the supply chain, partnering arrangements, and so on; and as the project to realize the business opportunity progresses, these elements all undergo changes. To the extent that the changes result in changes being required of the attributes of the technology components, the interface needs to be activated, and the consequences of the changes for the realization of the technology components are to be determined by engineering. This becomes an input to the change control process and to the decision whether to implement the proposed changes or not, and thus engineering becomes a partner in the business process.

13.3.3 The Engineering Paradigm

A previous publication, *The Engineering Paradigm* (Aslaksen 2013), introduced the concept of the *engineering paradigm*, inspired by the seminal work of Thomas Kuhn (1962), but in contradistinction to his use of the term in science, where it relates to the internal workings of the profession, the engineering paradigm relates to the external conditions under which engineering is performed. And the reason for this difference is, of course, that while science is self-contained, engineering has no existence except as it relates to industry, as noted earlier and illustrated in Fig. 13.2. It is now of interest to consider this paradigm in some detail under the particular perspective of the interaction with the business process, because, while there has been a great deal of work undertaken regarding the interface between engineering and society, particularly ethical aspects, little of it has focused specifically on the business interface. A number of references to study the interface between engineering and industry were provided earlier in this chapter; some recent work on ethics and engineering can be found in *Philosophy in Engineering* (Christensen et al. 2007) as well as in *Philosophy and Engineering* (van de Poel and Goldberg 2010).

In the Introduction we identified technology as a central component in the interaction between engineering and business, even though, as we then noted, the two parties have differing views on the meaning of "technology". An approach to understanding the role of technology in this interaction is to ask the following questions: what do engineering and business *use* technology for? How does technology enter into the process of engineering and the business process, and particularly into the interface between the two processes? In the case of engineering, the answer appears to be straightforward: as mentioned earlier on, technology is the resource engineers use to create applications that meet the needs expressed by the society or sections of the society. But if this resource is used unchanged in the interface with business, as it unfortunately too often is, it will be unintelligible to business; the access to this resource requires the education and experience of an engineer. So the use of technology by engineering in the interface with business needs to be different from the use within engineering; basically, it requires a translation into a commonly understood language.

While new business opportunities may often arise as a consequence of the close involvement of the business process with the market, this is by no means exclusively so. In many cases, and particularly in companies with a significant technology development capability, as opposed to buying technology, engineers may be the initiators both of new product development and of the associated project within the business project. But the interface between engineering and business still faces the same requirement for a common language. No matter on which side of the interface the idea for a new product originates, a successful outcome will depend on having a shared understanding of what success means.

Returning to the engineering paradigm, we observe that, in addition to any other changes in the interface of engineering with its environment, the interface with the business process requires a change (or improvement). This was recognized some time ago, as the following quotation shows:

> … we see that engineering is not fulfilling its intended role and, more significantly, is not really positioned to do so. In the overall process of wealth creation, which is a business process, engineering has been marginalized because it has failed to come to grips with the changing realties of that process. In particular, because of attitudes and self-imposed restrictions on the relationship between engineering and the other players in the process, engineering is not seen as a partner, but as an outside service called upon if and when required. (Aslaksen 1996).

And this is still largely true today. If we remain within the narrow focus on the engineering-business nexus – that is, ignoring that they are both social activities integrated into the same framework – we can identify one requirement that is common to them both and unites them in every project, and that is the requirement to make a return on the investment. Every project incurs a cost, and as some or all of this cost is incurred prior to the generation of any revenue, it is in the form of an investment. A single project may fail to make a return on the investment, but in the long run both engineering and business would cease to function if there was no return.

This common requirement forms an obvious starting point for a parallel, top-down execution of the engineering and business processes, and such an approach to project development has been proposed and described in considerable detail in several publications. However, it has found little resonance in either industry or academia, and the reasons for this are not difficult to discern. Firstly, very few textbooks on engineering design treat life cycle cost as a design parameter. While the engineering curriculum usually includes subjects on economics and basic accounting, this is seen as something outside of and additional to engineering, rather than being integrated into the design process. At most, cost is included in the form of cost estimating; one example of this is the otherwise excellent textbook *Engineering Design* (Pahl et al. 2007), which, it should be noted, is essentially limited to mechanical design.

Secondly, there is little interest within the engineering community, in industry or in academia, to give any quantitative attention to the value or benefit to be produced by any particular project, and "value engineering" is most often reduced to cost minimization. In the author's experience, the leaders in project economics and the most sophisticated economic models are to be found in the banking sector, and while banks may employ engineers in their teams, there is still a disconnect to the design effort.

Thirdly, there is often an ideological reluctance to put a monetary value on many applications of technology; their characteristics, both positive and negative, are seen to be on a "higher plane". Typically, such characteristics relate to safety, environmental impact, equality (economic, racial, gender), and so on. These are social values, and this is where the limitations on the strict engineering-business nexus become apparent. Both engineering and business are embedded in society, and their numerous interactions with society introduce both additional professional responsibilities and a certain strain in the engineering/business nexus.

In the case of engineering, this more complex environment constitutes the engineering paradigm. In addition to the direct and the indirect interfaces to industry and to the business process illustrated in Fig. 13.1, engineering is constrained by a great number and different types of legal and statutory requirements, as well as general technical requirements embodied in various standards. A view of standards as an interface between technology and society is presented in *Buckets of Resistance: Standards and the Effectiveness of Citizen Science* (Ottinger 2010). We shall look at the implications of this body of what might be considered "background" requirements for engineering as a profession in the next subsection; at this stage we need to realize that those requirements play a significant role in the engineering-business nexus. While they apply directly to the engineering process, they indirectly constrain both the opportunities and the responses business may consider; and it becomes a duty for the engineering side of the relationship to explain this to the business side and to provide advice.

The emergence of, and rapid increase in, this body of requirements is a measure of the importance of the application of technology in the economy and of its influence on the evolution of society; besides it represents one of three major components of the change taking place in the engineering paradigm. In a somewhat simplified way, it can be viewed as a change in the relative importance of two aspects of the engineering process: one is the project-specific aspect, the creative aspect of finding a cost-effective solution to meeting a need; the other is to ensure that the solution meets all the non-project-specific requirements, the "background" requirements. The balance is shifting towards the latter and, as a consequence, solutions tend to be more conservative and more in the form of adaptions of existing solutions, whereby compliance with the "background" requirements is easier to demonstrate, rather than in the form of bold innovations.

The second major component of the change taking place in the engineering paradigm is driven by the interface to science and mathematics. The advances in these fields are making demands on what might be called the "sophistication" of the engineering process. If we locate this process in a triangle with science, art, and trades at its apexes, engineering is continuing its move in the direction of science, as indicated in Fig. 13.5.

The third major component is the increasing importance and complexity of the interaction with society. In addition to the interaction through industry and business, which have been present for a long time, the realization that technology is a main driver of the evolution of society and that the features of the technological applications created by engineers translate into features of society, is adding a whole new dimension to engineering. This realization has been developed over the last hundred years or so, by philosophers, sociologists, and engineers; references to the relevant literature can be found in the two works already cited, *Philosophy in Engineering* (Christensen et al. 2007) and *Philosophy and Engineering* (van de Poel and Goldberg 2010), as well as in conference proceedings, such as those on the Workshop on Philosophy & Engineering (WPE 2008) and the Forum on Philosophy, Engineering & Technology (fPET- 2010).

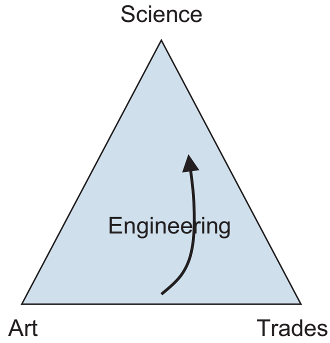

Fig. 13.5 The change over time in the relationship of engineering to art, trades, and science

These changes to the engineering paradigm – that is, to the environment in which the process of engineering takes place – call for changes to the engineering profession; to the definition, organization, and education of engineers. That is the subject of the next and last subsection of this chapter.

13.3.4 The Engineering Profession

The point of departure for this look at the engineering profession is provided by two facts: one, the volume of the resource base we have identified as technology is growing at some increasing rate. As was indicated in Fig. 13.3, new technology is being developed both through development projects based on new inputs from science and through new insight gained in the execution of application projects. The figure also indicates that technology becomes obsolete and is then removed; examples of this range from how to make a stone axe, via how to use a slide rule, to how to design vacuum tube circuits. The second fact is that the amount of information a human can store and process as useful knowledge is limited.

The obvious problem raised by these two facts, and the emerging solution based on information technology constitute the first challenge to the engineering profession. Along with other professionals, the engineer is becoming a prime example of *hybridization*, that is the phenomenon that in many situations the coupling between human and technological artefacts is so close that it becomes impossible to make a clear distinction between the two. This use of the word “hybridization” should not be confused with many other uses of the term, such as in genomic hybridization and social hybridization. It arose out of a philosophical inquiry into how humans use and relate to technological artefacts which revealed how technology *mediates* our relationship to our environment (nature and society). The identification of this approach as *technical mediation* is often attributed to Don Ihde (1990) and Bruno Latour (1993), but several other authors have also contributed to it, including the earlier work of Michel Foucault (1977) and, more recently, work by Peter-Paul Verbeek (2005). A much more extensive and detailed development, which sees the brain as one of three organs forming a "general organology" – the other two organs being technical artefacts and social organizations – is due to Bernard Stiegler (1998) and (2011). Space does not allow a discussion of Stiegler's work here, and it is by no means uncontroversial, as discussed in a collection of articles (Howells and Moore 2013); see also the review of this book in (Gratton 2015). However, a recent article by Pieter Lemmens (2015) sets out a view of Cognitive Enhancement (CE), based in part on Stiegler's work, that is highly relevant to the practice of engineering. In this view, the enhancement of human cognitive abilities by means of external technology applications will inexorably lead to an interiorization of these applications in the form of technological prostheses, which Stiegler calls *pharmaka*, and which result in permanent changes to the brain (i.e. the long-term memory).

This analogy with the medical concept is chosen because these prostheses can have beneficial (like medicine) or detrimental (like poison) effects on the cognitive individuation process. In the context of engineering, that process is the core of the creative process, and the realization that the interaction with technology applications can have a negative impact needs to be taken into account in the practice of engineering. Furthermore, as emphasized by Stiegler, we must realize that this interaction takes place in a particular social organizational environment – the third organ – and that the current form of this environment, capitalism, with its demand for exponentially increasing consumption, is not only unsustainable, as was discussed in *A Story of Us: Evolution and the Individual* (Aslaksen 2015b), but promotes the negative effects of interiorization.

Returning to the simpler (or less controversial) concept of hybridization, the situation is that, in many cases, the entity that interacts with the environment is a *hybrid* of human and technical characteristics; and while this concept can be projected into the future as actual physical hybridization with implanted devices, as predicted by Kurzweil (2012), engineers exemplify the concept right now. Spend some time in an engineering office and observe how engineers use their time. Some is spent interacting with others in meetings or over the phone or via email, but of the time spent on core engineering activities, particularly design, more than half is spent interacting with a software package. Even more tellingly, watch what happens if the network goes down: they all stand around chatting and drinking coffee, waiting for the network to get up again.

This hybridization raises a number of issues for the practice of engineering. The first one is concerned with the interface between engineer and computer. Even though they are two parts of the same hybrid, they are functionally very different and so, in order to perform a particular body of work, it needs to be structured to suit the capabilities of the two parts. This is no different to structuring the work flow through a production process, as e.g. in the unit operation of a chemical process, but there is little evidence of this happening in engineering. Consequently, one has to suspect that the hybrid is not operating very efficiently.

Secondly, it is important to recognize that this view of engineering (i.e. performed by a hybrid) introduces a segregation of the computer applications involved in engineering into two groups. In the first group are those applications that are supposed to be part of the hybrid, closely coupled to the human, and resulting in a hybrid capability that is greater than the sum of the capabilities of the two parts. In the other group are those applications that perform tasks that the human could do (and maybe used to do); they just perform the tasks much faster (and perhaps more accurately) than the human. Here there is no emergent increase in capability.

The current situation is that most of what is classified as engineering software programs are in the second group, but are run by engineers instead of by software operators. This is undesirable for several reasons. One, it is a waste of an engineer's education and experience. Two, there is usually a considerable amount of training required to run the software efficiently and to exploit its full capabilities. (How many engineers can even use all the functionality of Word or Excel?). We train operators to run complex machine tools; why would we not train operators to run complex software applications? Somehow engineering has not completed the transition from the mechanical age to the information age. Three, engineers may only use these applications from time to time, and so struggle to maintain a high level of proficiency.

The first group of software programs, which are in the category of CE and artificial intelligence, is still in its infancy, with, in the author's experience, few products employed by industry. But judging from the amount of activity in this category (not all related to enhancing engineering), and from the improvements in visualization as the interface between human and technology, it is reasonable to expect rapid progress. However, it is also the group in which the danger of negative effects on the cognitive ability is greatest. A very simple example would be a personal database/ search engine closely coupled through e.g. an audio-visual interface, so that, as the engineer formulates and develops a problem definition, the application brings up relevant information and suggestions. But in order to do this, the application must contain a highly developed process for forming associations, and it would be very easy to skew this toward a particular commercial or political ideology.

A third issue arises as a consequence of the increasing importance of technology applications for the evolution of society. Through our choice of applications and our use of them we have a significant impact on what society will look like tomorrow, and as engineers are the main creators of these applications, there is an implicit responsibility for the outcome. Discharging this responsibility requires not only that the engineering community concerns itself with the interaction between technology and society, but that it establishes itself as a credible partner in the social and political discourse.

Considering the changes to the engineering paradigm and the issues raised in the foregoing, the profession seems to have arrived at a fork in its development. One way forward is for the profession to continue broadly along its present trajectory, producing ever more sophisticated and powerful technology and applications on demand, and attacking the problems raised above only as they relate to this role. The other way is for the profession to reclaim its position in society and to provide the involvement and leadership role it had in Europe at the beginning of the twentieth century. Given the changes that have taken place since then and, in particular, what was the point of departure for this subsection, it is obvious that this will require a restructuring of the profession and of its place in the technical workforce. As has been treated in some detail in *The Future of Engineering* (Aslaksen 2015a), the increase in the volume of technology has so far been handled by an increasing *horizontal* specialization; that is, a subdivision into ever more narrowly defined technical disciplines, but with little or no *vertical* subdivision on a scale measuring the relative strength of embedding in society to that of embedding in industry. And, indeed, the two subdivisions would be closely correlated, with an increasing embedding in industry requiring an increasing degree of specialization, and *vice versa*.

Progress down this path would have to be driven by engineering education through a corresponding restructuring of curriculum and degrees; a possible scenario for achieving this was also outlined in *The Future of Engineering* (Aslaksen 2015a). However, there is a current trend in academia that works against realizing this change, consisting of treating engineering more as a science. Besides the appearance of such a term as "techno-science", it is now common for lecturers and professors to have no industrial experience at all. The analogy in medicine would be a professor of cardiovascular surgery who had never performed an operation. This trend does not mean that there is not often a strong link between academia and industry, but it means that this link is limited in scope to technical problem solving, without an appreciation for the business that provides the context within which the solutions have to operate. It also means that an important part of the education process – the transmitting of knowledge based on experience from one generation to the next – is left to what is, in the author's experience, a very haphazard activity within industry.

References

Aslaksen, E. W. (1996). *The changing nature of engineering*. Australia: McGraw Hill.

Aslaksen, E.W. (2012). *An engineer's approach to the philosophy of engineering*, Abstracts of fPET-2012, the Forum on Philosophy, Engineering and Technology conference, hosted by the University of the Chinese Academy of Sciences in Beijing, November 2–4, 2012. To appear as a chapter in a volume in the Springer POET Series.

Aslaksen, E. W. (2013). The Engineering Paradigm. *International Journal of Engineering Studies, 5*(2), 129–154.

Aslaksen, E.W. (2014). *Engineers and the evolution of society*, Abstracts of fPET-2014, the Forum on Philosophy, Engineering and Technology conference, hosted by Virginia Tech, May 27–29. To appear as Chapter 15 in *Philosophy and engineering: Exploring boundaries, expanding connections*, D. Michelfelder, B. Newberry, and Qin Zhu, Springer POET Series.

Aslaksen, E. W. (2015a). The future of engineering. *Journal and Proceedings of the Royal Society of New South Wales, 148*(457 & 458., 2015), 159–165.

Aslaksen, E.W. (2015b). *A story of us: Evolution and the individual*, Gumbooya Pty Ltd, available at www.gumbooya.com

Christensen, S.H, M. Meganck, & B. Delahousse, (2007), *Philosophy in engineering*, Academica. Section 3: *Ethics and engineering*, six contributions.

Durkheim, E. (1893). *De la division du travail social*, Presses Universitaires de France. English edition: *The Division of Labor in Society*, trans. W.D. Halls, intro. L.A. Coser, Free Press, 1997.

Foucault, M. (1977). *Discipline and punish. The birth of the prison*, Random House.

fPET (2010). *Abstracts*, D.E. Goldberg & D.P. Michelfelder. http://philengtech.org/wp-content/uploads/2010/05/fPET2010-abstracts-5-1-2010.pdf

Gratton, P. (2015). Review of *Stiegler and technics*. Notre Dame Philosophical Review, available at https://ndpr.nd.edu/news/47481-stiegler-and-technics/

Howells, C., & Moore, G. (2013). *Stiegler and Technics*. Edinburgh: Edinburgh University Press.

Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Bloomington, IN: Indiana University Press.

Kidder, T. (1981). *The soul of a new machine*. Boston: Atlantic – Little, Brown.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. University of Chicago Press.

Kurzweil, R. (2012). *How to create a mind*. Viking Adult. This is his latest book, but a list of predictions can be found at https://en.wikipedia.org/wiki/Predictions_made_by_Ray_Kurzweil

Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.

Layton, E. (1971). *Revolt of the engineers: Social responsibility and the American engineering profession*. Cleveland: Case Western Reserve University.

Lemmens, P. (2015). Cognitive enhancement and anthropotechnological change: Towards an organology and pharmacology of cognitive enhancement technologies. *Techné, 19*(2), 166–190.

Macfarlane, I. (2015). *Science and innovation: Building Australia's industries for the future*, and B. Shorten, *Response*, Hansard, OzParltHR-17Aug15.docx.

Murphy, M, M. Dyrenfurth, G. Bertoline (2012), *Examining the identities of engineers, technologists and engineering technologists*, Abstracts of fPET-2012, the Forum on Philosophy, Engineering and Technology conference, hosted by the University of the Chinese Academy of Sciences in Beijing, November 2–4, 2012. To appear as a chapter in a volume in the Springer POET Series.

Newberry, B. (2007). Are engineers instrumentalists? *Technology in Society, 29*, 107–119.

Noble, D. F. (1977). *America by design: Science, technology, and the rise of corporate capitalism*. New York: Alfred Knopf.

Ottinger, G. (2010). Buckets of resistance: Standards and the effectiveness of citizen science. *Science, Technology, & Human Values, 35*(2), 244–270.

Pahl, G, Beitz, W., Feldhusen, J., Grote, K.H. (2007). *Engineering design*, (Wallace and Blessing, transl. and eds.), 3rd ed., Springer.

Stiegler, B. (1998). *The Fault of epimetheus*, vol. 1 of *Technics and time*, Stanford University Press.

Stiegler, B. (2011) *The decadence of industrial democracies*, vol. 1 of *Disbelief and discredit*, Polity Press.

van de Poel, I., & Goldberg, D.E., (2010). *Philosophy and engineering*, Springer. Part II; *Ethics*, ten contributions.

Veblen, T. (1921). *The captains of finance and the engineers*, 61, in *The engineers and the price system*, B.W. Huebsch, Inc. New York.

Verbeek, P.-P. (2005). *What things do: Philosophical reflections on technology, agency, and design*. University Park, PA: Pennsylvania State University Press.

Winner, L. (1995). *Citizen virtues in a technological order*, Ch. 4. In A. Feenberg, & A. Hannay (Eds.), Technology and the Politics of Knowledge. Indiana University Press.

WPE (2008). *Abstracts*, D.E. Goldberg and N. McCarthy. http://philengtech.org/wp-content/uploads/2009/08/wpe-2008-abstract-papers.pdf

Erik W. Aslaksen M.Sc. in Electrical Engineering from the Swiss Federal Institute of Technology in 1962 and Ph.D. in physics from Lehigh University in 1968. He is a Fellow of INCOSE, Fellow of the Royal Society of New South Wales, member of the Australian Institute of Physics, and a Director and Charter Member of Omega Alpha, the systems engineering honor society. Dr. Aslaksen's experience, gained in the US, Switzerland and Australia, covers fields as diverse as microwave components, power electronics, quantum electronics, communications, transport infrastructure, and industrial plant, and ranges from basic research to corporate management. In recent years his main interest has been in the area of philosophical aspects of engineering and the interaction between technology and society. He is a Director of Gumbooya Pty Ltd, and is the author of six books (one with W.R. Belcher) and over eighty papers and book chapters.

Chapter 14
Identifying Value in the Engineering Enterprise

James Trevelyan and Bill Williams

Abstract The investigation presented in this chapter was originally inspired by the authors' observations of engineers in Australia, India, Pakistan, and Portugal that suggested the value aspect of their work was rarely addressed. This is somewhat surprising given that value creation lies at the core of any business and nearly all of the engineers observed were working for business enterprises. This initial observation led us to examine what turned out to be relatively sparse literature relating to engineering value, how the value of engineering work is perceived within the context of entrepreneurship and innovation research and how students are introduced to this in engineering education programs and entrepreneurship courses. We were led to conclude that the concept of value creation makes only a tenuous and indistinct appearance at the far periphery of engineering discourse. Given the critical importance of business investment for almost all engineering enterprises, it is surprising that the research literature is almost silent on this issue. In the study we identify ways that engineers create and protect value that are not usually mentioned in the innovation-centred approach typical of entrepreneurship research and education emanating from Schumpeter's early twentieth century ideas that still shape business and economics today. We hypothesize that this lack of awareness of value creation by engineers may be associated with low success rates of major engineering capital expansion projects such as process plants, infrastructure construction, and defence equipment acquisitions. Furthermore, it could help to explain some of the everyday frustrations encountered by engineers, employers and investors in engineering enterprises and low rates of productivity improvement in developing countries.

Keywords Engineering practice · Value creation · Economics · Engineering education · Entrepreneurship · Engineering philosophy

---

J. Trevelyan (✉)
Mechanical Engineering Department, The University of Western Australia,
Perth, Western Australia, Australia
e-mail: James.Trevelyan@uwa.edu.au

B. Williams
CEG-IST, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_14

14.1 Introduction

Over the last decade the authors and their research associates have collected empirical data on engineers in the workplace using surveys, semi-structured interviews and field studies. In surveys and over 350 interviews and 10 field studies in Australia, India and Pakistan (Trevelyan 2016) and 23 interviews in Portugal (Williams and Figueiredo 2015) it was noticeable that when participants were asked about the most memorable contributions they had made during their engineering careers their responses emphasized technical artefacts or processes they had been involved in creating. One might assume that the contributions created value for their enterprises and clients but value was rarely mentioned and, when it was, mostly as the value of a variable quantity (such as length, pressure or temperature) or a specific monetary value (Trevelyan 2012). When prompted in two studies focusing on this issue, responses focused primarily on efficiency improvements and cost minimization (Crossley 2011; Singh 2015).

While some engineers did tell us that checking work costing a few thousand dollars can prevent mistakes in construction that can cost millions of dollars, very few of our participants described checking and review work in terms of increasing project value by reducing both real and perceived risks for the investors (Trevelyan 2012; Mehravari 2007).

In this study we first examine literature relating to value creation by engineering enterprises in business research, technological innovation, engineering management, engineering education and entrepreneurship publications. We continue with a discussion on different conceptions of value in the business literature and we go on to trace how Schumpeter's concept of *creative destruction* (Schumpeter 1942, 1950, Ch 7) and his writing on the importance of innovation for value creation in firms has strongly influenced thinking on entrepreneurship and the role of engineering.

Drawing on empirical studies on engineering practice since the 1970s, including our own and those of our research associates, we go on to identify a number of aspects of engineering value creation relating to investment risk reduction, due diligence and maintenance work. We propose that engineering activities are also directed at "value protection", the avoidance of economic value destruction and show how such destruction can occur in the absence of appropriate engineering activity. We position these aspects of technical work in Schumpeter's concept of *circular flow;* in this respect our argument clearly goes beyond the considerable volume of business research derived from Schumpeter's work that sees technological innovation as the essential engineering activity that generates value.

Derived from this analysis, we indicate areas of research into engineering practice that we believe could result in significant financial savings in large scale engineering projects. In addition, we suggest that including these aspects of engineering value creation in mainstream engineering education and the growing number of entrepreneurship courses offered to engineering students would help graduates develop a stronger appreciation of the value of their professional contributions. On reflection, it is surprising that value creation is not central in engineering education: it is puzzling that students are left to figure out the purposes of engineering for themselves.

It is also worth pointing out the difference between perspectives on value from within the private enterprise system that frames this chapter and alternative societal perspectives. For example, Ulrick Jørgensen and Jens Stissing have described valuation criteria that can be adopted in the social space where public goods are the main concern (Jensen and Jørgensen 2018).

14.2 Literature Review

The argument in this chapter is based on four primary areas of research discourse which we will outline in this section: value and its creation through business innovation, wealth creation, engineering design and finally engineering education. We then go on to draw on our own engineering practice research in Sect. 14.3. The present chapter only permits a sampling of relevant discourse and we are open to suggestions from readers on literature that might strengthen, or point to the need to strengthen the arguments presented here.

14.2.1 Value Creation in the Firm: The Business Perspective

Value and its creation have received extensive attention in the business research literature particularly since Michael Porter's exposition (1985) of the value chain concept (Fig. 14.1.). He described value in terms of the price difference between a firm's products or services and all the inputs needed to produce them. Porter used this to explain how customer value accumulates through different activities within a firm that result in an end product or service delivery and he claimed that firms that successfully create value in the various parts of this chain are likely to have a *competitive advantage* over their immediate competitors.

While Porter mentioned engineers, he did not describe their roles or value contributions in detail. His discussion on product differentiation contrasted engineers' and plant managers' perspectives with those of purchasing department clerks (Chapter 4), pointing out the complexity of buying decision making processes in typical customer firms. His chapter on technology development placed engineers in key roles alongside other specialists (Chapter 5). Even though several of his case studies focused on enterprises for which engineering is a core specialization (e.g. power generation, chain saw and electronics manufacturing), engineering contributions remained in the background of his discussion.

Porter also drew attention to the "value system" concept: firms trade with each other in a network or ecosystem (Adner and Kapoor 2010) buying components and materials from some firms and selling products that reach ultimate buyers or customers through one or more buying firms (or "channels"). The core of his value creation perspective rests on maximizing the prices that buyers pay for a firm's products or services and minimizing the costs of all the inputs needed to produce them.

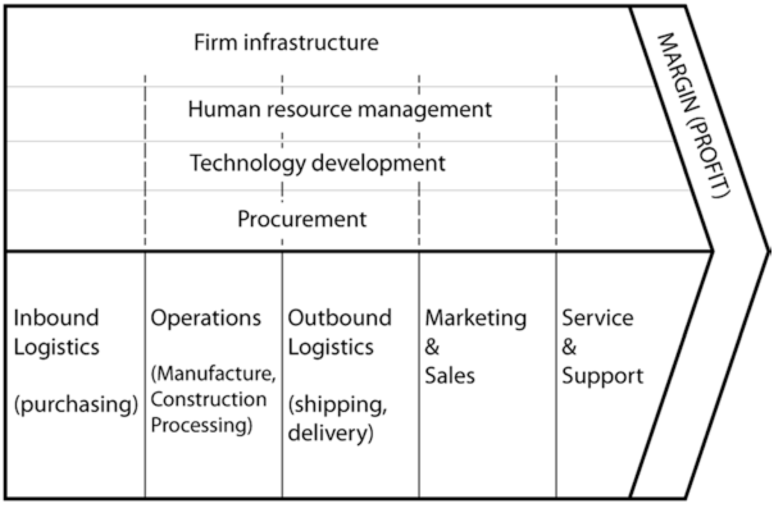

Fig. 14.1 Value chain. (Porter 1985)

Despite the qualitative nature of Porter's descriptions, with unclear empirical foundations, this view of the firm has become a cornerstone of business school teaching. However, the links between engineering and value creation have received little more attention since then, except in the context of innovation, and much of that focus has been in the context of information technology (IT) enterprises. Beyond IT and innovation, there is scant literature linking value creation and engineering.

Porter's understanding of value is just one of several in the business literature today. Service industries have become a much more significant focus of discussion as they have steadily displaced manufacturing in western economies and, as a result, ideas on value creation have evolved beyond buyer price maximization. Several distinct understandings of value creation have emerged though, as Ng et al. (2010) remarked in their discussion on value co-creation in service delivery, these often come with implicit underlying assumptions. Building on the etymological origins of the word, they explain two meanings for "value". The first refers to a virtue based in an ethical position, an abstract notion of what is held by an individual to be intrinsically good, such as honesty. The second describes a measure of "goodness" in an object, an activity, or even a person, for example to describe the value of a theory contributed by a philosopher.

The second meaning leads to axiology, the philosophical study of value and what is valuable, and the assignment of value to items. Ng et al. (2010) explained how axiology leads to the conclusion that value is not an intrinsic property of an item: like beauty, it depends on the perceiver(s), and arises from a conscious human experience. Value, therefore, can only be "co-created" through the experience of the beneficiary on accepting the provider's value proposition. This value is referred to as "use-value" reflecting the importance of human experience that gives rise to the subjective perception of value.

Ng et al. (2010) also explained how the business literature has a natural tendency to associate "value" with the axiological term "exchange-value". A long history of commerce based on making and selling products has contributed to the strength of this association. Exchange-value is the amount of money or other goods exchanged in return for an entitlement to an object or service. The experience of entitlement, possession or use of the exchanged object or service, or experience of the exchanged service leads to a subjective perception or perceptions of use-value. Take an insurance policy, for example. The premium represents a monetary value exchanged in return for peace of mind knowing that in the event of an unpredictable loss or catastrophe financial compensation will be provided by the insurer. Naturally, the subjective experience may subsequently be influenced by frustration experienced when lodging a claim and receiving less compensation than expected as a result of not having thoroughly understood all the policy exclusions presented in fine print!

Thus, in business literature, the term "value" tends to be associated by default with exchange-value rather than use-value, and the distinction between the two tends to be overlooked in many research discussions. Not only is there a degree of confusion between the two terms, but there are several different ways in which value creation is described.

Even within the subset of business research literature associated with innovation, we can find several distinct interpretations of value creation in the context of a firm, stated below with examples drawn from recent literature.

- Increase in share value or total value of common stock, reflecting stock market perceptions of future performance (Mizik and Jacobson 2003; Moore and Manring 2009; Kelm and Narayanan 1995; Kohers and Kohers 2000; Lavie 2007),
- Increase in profitability (Zhu et al. 2004; Lavie 2007; McNair et al. 2001),
- Increase in market share (Adner and Kapoor 2010),
- Increase in sales volume or sales distribution (Zhu et al. 2004),
- Increase in asset values (Kohers and Kohers 2000; Jacobides et al. 2006),
- Decrease in production and input costs (McNair et al. 2001; Porter 1985), or
- Product quality improvement or customization to achieve higher product sale price (Franke and Piller 2004).

Value creation has also been associated with practices within a firm such as developing an improved understanding of customer needs and developing relationships with customers. For example, Amit and Zott (2001) gathered extensive information on the performance of IT firms from diverse public domain sources and arranged for researchers with IT firm insights to analyze the information and write responses to a series of open-ended questions exploring possible aspects of value creation. Using qualitative analysis on these responses, they identified specific attributes and practices adopted by the firm that employees associated with value creation. For example, employees thought that software products can create greater value when it is difficult for customers to switch to a competing product, termed "lock-in". Zhu et al. (2004) relied on perceptions of senior employees within IT firms to identify practices they associated with value creation. Köbler et al. (2009) identified the practice of adapting after-sales service and support for medical equipment to meet different customer needs as a means for value creation. Developing relationships with customers, sometimes with loss-making product sales or services, especially for SMEs, has also been proposed as value creation practice in engineering (Walter et al. 2001).

Value creation can also be conceived as taking place in sequential steps or phases rather than a single set of concurrent processes. For example, Mizik and Jacobson (2003) distinguished between value creation, citing research and development as an example, and value appropriation, citing advertising as an example, and demonstrated that shifting resources to the latter tends to create more expectations of future value creation as judged by the firm's stock valuation. Kelm and Narayanan (1995) drew a similar distinction, referring to the innovation phase in which research and development is the principal wealth creation practice, and the commercialization phase in which marketing becomes much more significant.

The business literature also reveals how business networks, clusters of firms and "ecosystems", become the context in which value creation takes place rather than a single firm (Adner and Kapoor 2010). For example, Lavie (2007) introduced the notion of business network architecture as a means of value creation by investigating the stock market performance of software firms with different kinds of alliance relationships with similar firms, while Costa and Baptista (2012) analyzed factors affecting value within an ecosystem of firms producing plastic injection moulds.

In summary, therefore, the business research literature frames contemporary ideas on value creation in terms of Schumpeter's ideas of economic development, specifically innovation. While engineers are clearly central in technological innovation, their roles remain relatively unclear from the point of view of business discourses. We will show later in this chapter how the comparatively recent emergence of a body of engineering practice literature can help clarify their roles.

Recent discussions on service enterprises are helping to shift the focus from simplistic ideas of exchange-value, the prices paid for goods and services, to the underlying subjective human experiences, or use-value, that motivates purchase decisions. Since engineers themselves tend to provide services and information rather than tradeable products, the deeper understandings of value emerging in contemporary business literature could help frame ideas on how engineers create value in the business enterprise.

14.2.2 Technology and Wealth Creation: The Macroeconomic Perspective

Economic growth, the outcome desired by most economic policymakers and political leaders in the world today, is widely considered to depend on an appropriate combination of entrepreneurship and technological change. The transition from an agrarian subsistence economy to an advanced post-industrial society is associated with large improvements in personal security, health, life span, and living standards and most societies today are working on transforming themselves in a similar direction. Successful transition depends in large part on large productivity improvements in which engineering plays a critical role by enabling people to achieve more with less effort and material resource consumption (Manyika et al. 2015, p.13–14). Greater productivity enables people to move from essential production of food, shelter and clothing to investment in human capital: security, education, healthcare and social welfare. As a crude example of this productivity change, we can compare a typical South Asian country such as Pakistan with Australia, a typical advanced economy. Pakistan requires about half of its workforce to be engaged in food and water production yet still does not manage to sustain healthy nutrition for its citizens, nor provide social welfare (World Bank 2016; Bhutta 2011). High level education is only accessible for the wealthy elite. On the other hand, Australia manages not only to feed itself but also exports a large food surplus with around 2% of the workforce, and subsidized higher education is available for the most able 35% of the population. Both Pakistan and Australia require new technologies to improve productivity still further in order to transition to production systems that are sustainable in the long term, and engineering will be important in those transitions.

Economists have searched for policy prescriptions to promote productivity improvements and economic growth. Improvement in the availability of systematically collected data over the last few decades has allowed the development of complex economic models such as the Global Entrepreneurship Development Index (GEDI: Ács et al. 2014) that allow economists to investigate the effects of technology usage and other factors on economic growth, inequality, human life-span and health. Just as in the preceding discussion on value creation in the firm at the micro-economic level, the conceptual foundations can be traced back to the writings of Joseph Schumpeter on which Michael Porter built his arguments relating to firms and later national competitive advantage.

Schumpeter (1911: 1934) described the normal economic system as "circular flow" running in channels essentially the same from year to year (p. 61). He described "economic development" as discontinuous changes in this pattern of flow caused by innovations emerging from special actors in the system: entrepreneurs. They innovate by following one or more of five possibilities (p. 66):

(a) Introduce a new good, displacing one or more existing goods from the market,
(b) Introduce a new production method,
(c) Open a new market for an existing good,
(d) Secure access to new materials or components, or
(e) Reorganise, such as creating or destroying a monopoly.

Schumpeter went on to discuss the necessity of capital and also special leadership that comes from the entrepreneur who can perceive the need for change, has the vision of what is possible to meet that need, and has the personal authority and influence to mobilize the resources needed to make change happen (p. 74).

Self-evidently, each economic development step holds the promise of increased value creation, though who appropriates the resulting exchange-value can depend on particular circumstances.

In writing his book, Schumpeter was contributing to the debate at that time on whether unplanned capitalism or socialism with a planned economy would bring greater benefits. This, after all, was the critical issue of the time when he was writing: the struggle between the capitalist West and the communist East. Would capitalism ultimately succeed in this titanic struggle? A question that to us now, 25 years after the collapse of communism, seems academic was seen as critical at the time of his writing, so his ideas on economic development were woven into his contributions to this debate. Writing in the 1930s on socialism and democracy, Schumpeter included an echo from his first book describing his idea of "creative destruction" (Schumpeter 1942, 1950, Chapter 7). Parting from his argument on whether capitalism required special controls on monopolistic behavior by firms, he showed how innovation, partly prompted by competition between firms, can overturn the largest and strongest monopolies, leading to benefits for everyone, not just the owners of capital.

Building on these ideas in the search for effective economic policies to promote societal goals, economists have modelled economic development by combining the influence of technology in combination with rules of economic behavior (or policy settings) and human capital, representing human abilities acquired through education and learning from experience (Romer 1990). Policymakers understand that social development is dependent on productivity so that resources can be invested to improve human capital through education, healthcare and social welfare (Manyika et al. 2015, pp. 13–14). Porter et al. (2002) suggested that the relationship between entrepreneurship and economic development could be described as being made up of three stages (Fig. 14.2.) and that a region or country with high levels of entrepreneurship would manifest high levels of economic development.

The *factor-driven stage* is marked by high rates of agricultural self-employment seen in South Asia today with high reliance on agricultural commodities and low value-added products. Almost all economies have experienced this stage of economic development in the past. This phase has not been associated with formal knowledge production, though clearly knowledge is accumulated as small enterprises improve the efficiency of their production systems.

Transition to the *efficiency-driven stage* is said to depend on higher productivity in large markets allowing companies to exploit economies of scale. The large industries in this stage are manufacturers that provide basic services. The efficiency-driven stage is also marked by decreasing rates of self-employment. As technology allows capital to substitute labor, incomes rise and employment shifts from rural agriculture to urban-based industries.

The *innovation-driven stage* is marked by an increase in high value-added knowledge-intensive activities (Romer 1990) in which entrepreneurial activity is important. Differences in microeconomic aspects of entrepreneurship activity seem to be correlated with economic growth (Ács et al. 2014).

Even though there has been GDP growth in developing countries in the last 50 years, only South Korea has managed to transition to an advanced economy: the productivity gap between developing countries and leading economies has hardly changed (Manyika et al. 2015, pp. 45–46). Both Ács (2010) and Romer (2010)

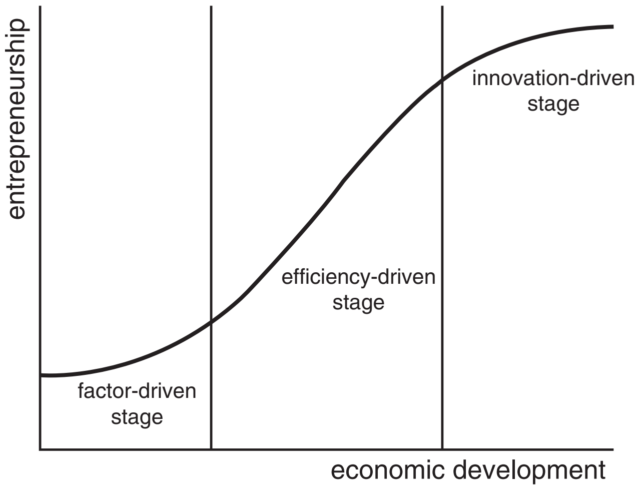

Fig. 14.2 S-curve model of entrepreneurship and economic development (Ács 2010)

argued that entrepreneurship and economic development could be encouraged in developing countries by policy changes. Romer (2010) argued that technology could cross national borders to promote catch-up growth because it consists of instructions for "mixing together raw materials" that can be transferred at near zero cost. Only the rules prevailing in a country's economic system need changing, though at some cost. In a similar way, Ács (2010) argued that incentive structures need changing to avoid what Baumol (1990) called unproductive or destructive entrepreneurship and Murphy, Shleifer, and Vishny (1993) called rent-seeking by powerful social actors. Interestingly, neither of these reports mentioned any contemporary data from developing countries: Baumol relied on intriguing historical analogies and Murphy et al. on mathematical arguments.

It is now taken for granted that technological changes have led to the rapid advances in prosperity and living standards we have seen in the last 150 years. One of the ways Schumpeter's ideas have played out is encountered in discussions on technological innovation where value creation is said to depend on innovation which in turn depends on entrepreneurship. Here there is a risk that we can overlook how value can be created or destroyed in ordinary economic activity by engineers, the "circular flow" that Schumpeter referred to. Whereas there are many reports of value creation in association with technical innovations, very little attention has been devoted to understanding how engineers influence value creation in economic activity where there is little or no technical innovation. Recent concerns about stagnant productivity growth in Britain, for example, where engineering enterprises form a very large sector in the economy and a dominant component of productivity measures, have highlighted remarkable reluctance by businesses to invest even with record low interest rates (Dolphin and Hatfield 2015). Similar issues are being discussed in other countries such as the USA and Australia (Boyd 2013; D'Arcy and Gustafsson 2012). However, contemporary economists seem unable to agree on the causes or policy cures with a wide divergence of positions among competing ideas (Manyika et al. 2015).

From the perspective of macroeconomics, therefore, engineering is subordinated to economic policy settings that determine the rules and incentives in which economic actors, firms and individuals, choose to invest their resources. Engineering is one choice of many investment possibilities. Technology is broadly equated with explicit knowledge that can be reproduced and transmitted easily (excepting intellectual property restrictions).

Even though the significance of innovation and engineering in productivity improvements and thus economic growth is well accepted, most engineers are employed in enterprises that form part of Schumpeter's "circular flow" and have little if any role in innovation. In the UK for example, the engineering sectors in 2014 contributed £455.6 billion to GDP (27.1% of total) and employed 5.53 million of whom 3.63 million were engineers and technicians (Kumar et al. 2016, pp. 1, 58). A further 1.34 million engineers and technicians were employed in non-engineering enterprises. Private and government sponsored innovation and research (including sciences) totalled £27 billion (only 1.6% of GDP) in 2013 (Kumar et al. 2016, p. 37), so we can readily conclude that engineers employed in these sectors represent only a small minority. Ordinary everyday engineering dominates an industrialized economy. Therefore, in order to understand how engineers influence macroeconomic phenomena, we need to understand their contributions in day to day engineering practice where innovation is not a priority and may even be avoided. Hence, it is not sufficient to focus on innovation, research and development as the sites of economic value and wealth creation: we need to look further afield.

14.2.3 Value Creation Through Design: The Engineering Perspective

Within engineering literature, on the other hand, value creation is hardly ever mentioned at all. When it is mentioned, value creation appears as a more diffuse concept with even more levels of implied assumptions. For example, Shimomura et al. (2006) associated value creation with improving the "producer-consumer interface" in the context of providing engineering design services, but the means by which value is created is unclear in their text. Yannou and Bigand (2006) reviewed the long-standing practice of "value-engineering" and associate value creation with framing design requirements in terms of engineers' perceptions of customer needs. Behind these discussions there are several implicit and possibly questionable assumptions, for example, that engineers can reliably represent customer needs without direct involvement of customers or end users in the design process. It is not clear whether the discussions refer to exchange value for engineering designs or the products themselves, or indeed who is considered to be the customer. Moore and Manring (2009) advocated "sustainability value" in a discussion on value creation, pointing out how changing community and corporate values (use-value) are influencing investor value perceptions (exchange-value). While simultaneously discussing fundamentally different ideas in terms of "value" the actual value creation seemed to rely more on assumed connections between engineering activity and investor sentiments.

Zhang and Gregory (2011) took a more systematic approach in their analysis of global engineering supply networks. They proposed detailed versions of the Porter value chain and value system network models for global engineering network organizations. Their main focus was on "the transformation process from ideas into innovative products and services" reflecting implied assumptions that value is created as a result of innovation. However, they also considered value creation through two other engineering activities: efficiency-seeking and flexible responses to customer needs. With regard to engineering efficiency-seeking they suggest that "an efficient engineering network will create value through minimizing waste and maximizing capability utilization." While flexible responses, they argued, add value by improving adaptation in uncertain circumstances.

Some contributions to the engineering literature do reflect contemporary research in the business literature. For example, the arguments set out in Sect. 14.2.1 by Ng et al. (2010) were reflected by Rankin et al. (2009) in discussing service quality experienced with IT systems. They emphasized the additional value created through human mediation: the service can be more readily adapted for the needs of different individuals. In the case of simple non-adaptive products, where it was argued that a service is still the essence of what is being provided (Ng et al. 2010, p. 7), there will always be a more limited subset of individuals who experience a given use-value. However, when human mediation or interaction is feasible, the service will provide similar use-value with a larger range of human preferences (Köbler et al. 2009; Ng et al. 2010, pp. 10–11).

Another approach for accommodating a greater range of recipient preferences is customization, in which a variety of similar products are available to suit different buyers (Franke and Piller 2004). However, others caution against excessive customization. It is possible to offer interactivity and product customization in ways that alienate recipients rather than satisfying them (Sköld and Olaison 2012): they reported how a firm providing highly customized heavy haulage trucks encountered recipients desiring levels of interaction with the firm that could not be reasonably provided, and in declining further interactions managed to alienate their customers.

Engineering discourse on value is complicated by alternate interpretations of the word. In addition to the two meanings identified up to now, use-value and exchange-value, in the engineering workplace context we find that "value" takes on a third distinct sense. Value is widely used by engineers as a numerical or other abstract measure associated with a spreadsheet or calculation result, or with a mathematical symbol (Trevelyan 2012). For example, the solution of a particular equation written in terms of the variable x could lead to a value for x calculated to be, say, 42.76254. Engineers will also often use "value" to refer to the total expenditure required for an engineering activity. Given the tendency among engineers to assume standardized meanings for terminology (Trevelyan 2014, Chapter 7), it is perhaps not surprising that discussing alternative notions of "value" poses challenges for engineers.

There are instances when the third meaning of value merges with the second meaning, as in Pessôa et al. (2006) discussing value-driven design of a tail parachute for an aircraft. Design features satisfying stakeholder requirements were labelled as "value items" in this discussion. Value items (second meaning) such as "parachute riser length" and "cross section", were not really values (third meaning), but point solutions defined (i.e. the values (third meaning) for these variable design parameters were fixed, or at least confined to a narrow range of possible values (third meaning) early in the design process)."

14.2.4 Value Creation: The Engineering Education Perspective

Just as in the wider engineering literature, value creation seldom intrudes on engineering education discourse, even as a research topic. However, entrepreneurship education has gained a foothold in some engineering schools. In that sense, we can say that value creation has an acknowledged place by proxy, yet still a marginal place, in engineering education (Besterfield-Sacre et al. 2016). The consequence of this change in emphasis in at least some engineering schools is the subject of Chap. 20 by Anders Buch and Joakim Juhl and also Chap. 17 by Mike Murphy, John Jameson and Pat O'Donnell.

Analysing abstracts in the European Journal of Education over the 6 years from 2010 to 2015 (293 in all) we find that value creation appears in none of them although entrepreneurship is mentioned in three. Entrepreneurship is mentioned in only one abstract from the 155 articles published in the Journal of Engineering Education over the same period and the same abstract is also the only one that refers to value creation. While entrepreneurship is included in the taxonomy of engineering education research (Finelli et al. 2015) currently used by various engineering education research journals to suggest keywords to authors, we note that neither value nor value creation is included among the 455 terms listed. Based on these data we could conclude that entrepreneurship has a relatively low priority in the field and value creation even lower.

Entrepreneurship education has become firmly anchored within business schools, however. Entrepreneurship education began in business schools in the US in 1947 and has since spread widely through higher education in the US and Europe (Katz 2003). In the US there are over 2200 courses at 1600 schools (Katz 2003, p. 284).

These courses typically consider successful entrepreneurship in terms of "energy, innovation and market orientation" (Katz 2003, p. 296). Engineering institutions have also increasingly begun to include them in their programs. Arizona State University, for example, includes entrepreneurship in all programs for its 83,000 students (including 19,000 engineering students) and currently offers nearly 90 entrepreneurship courses. In Europe and many other countries, entrepreneurship education is following US models and is rapidly becoming as significant as in the US (Katz 2003, p. 296).

Entrepreneurship education in the context of engineering education has been promoted as the best way to bridge the differences between technical and business interests, and to promote career opportunities for students with technology start-ups (Creed et al. 2002). Interestingly, evaluation of entrepreneurship courses is frequently carried out by assessing students' career intentions to pursue self-employment or work in small technology start-ups. Proponents have adopted what might be termed as a proselytising attitude, referring to the need to change the "mind-set" among students and engineering faculty (Duval-Couetil 2013, pp. 397, 402; Besterfield-Sacre et al. 2013).

However, not everyone involved in engineering education subscribes to this view. Even in the early years of the twentieth century, before the publication of Schumpeter's books, there were signs of tensions between technical and business interests when the MIT Electrical Engineering department ran a course in cooperation with the General Electric company (Carlson 1988): "there was an on-going debate over the exact role that the college-trained engineer should play in American business: was he to be a factory supervisor, a highly paid technician, a scientifically trained designer or a corporate executive?" Even at that time, businesses emphasized the importance of activities that seemed to academics as relatively mundane tasks such as quality control, inspection and maintenance. Similar tensions between technical and business interests can be seen in engineering departments today (Quinlan 2002; Gilbuena et al. 2015).

14.3 Engineering Practice Research Findings: Workplace Perspectives on Value Creation

With a tiny number of exceptions (for example Youngman et al. 1978), empirical studies of engineering practice to investigate day-to-day workplace performances by engineers have only appeared in the last 10 years. Before then, relatively little was known about engineering practice (Trevelyan and Tilli 2007; Barley 2005) and even today the available literature is yet to make a significant impact on engineering education, practice or the perception of engineers' work in other fields of research. Even though we still have relatively few empirical investigations to draw upon, it is nevertheless possible to outline emerging workplace perspectives on value creation.

An engineering enterprise is an organization that depends on the application of specialized knowledge that emerges from engineering schools and allied communities of practice. An enterprise is not the same as a firm or company. The people involved can come from several different firms, all collaborating with the same purpose – delivering a product, a service, or information. Even the customers, clients, and end users are part of the enterprise: without their knowledge of how to use the products and services, as well as their willingness to pay for it, there would be no enterprise. The investors who provide finance also play an integral role. The people in the enterprise are not all engineers; in fact, there may be very few engineers and they may represent a very small minority of the people involved. Engineering relies on many different people collaborating, including the financiers, clients, end users, consultants, and even government regulators (Trevelyan 2014, Chapter 5).

Despite the emphasis in the business literature on technological innovation, only a small proportion of engineers are directly involved in such activity. Most of the work performed by engineers is aimed at securing effective collaboration in engineering enterprises. Furthermore, recent data show that engineers spend only a small proportion of their working time on obviously technical activities. Empirical studies of engineers in their workplaces in Australia, Asia and Portugal (Trevelyan 2016; Williams and Figueiredo 2015) found that the participants typically spent relatively little of their working week involved in activities that *could have entailed* design or innovation development (less than 15%, and in most cases less than 7%). Technical coordination, project management and testing and inspections, for example, involved significantly more (60%) (Trevelyan 2007; Trevelyan and Tilli 2008). Moreover, as we shall demonstrate, in many engineering enterprises innovation is deliberately avoided for commercial reasons.

The authors' research also revealed that most engineers did not talk about value creation in the research interviews unless prompted with specific questions (Crossley 2011; Singh 2015; Trevelyan 2012). When prompted, most engineers identified similar efficiency improvements to those identified by Zhang and Gregory (2011) but few discussed, for example, creating value for their clients, or the significance of risk and uncertainty in value perceptions. Value was a challenging concept for most engineers to describe beyond the idea of a numerical value in a spreadsheet, often the total expenditure on a specific aspect of engineering work.

Several participants drew attention to what they perceived as a high rate of engineering project mistakes and financial failures, though none had access to quantitative data to confirm their perceptions. Quantitative data has since been published and the results are discomforting for many engineers.

Commercial data reveals the low success rates among major engineering capital expansion projects. Examples include construction of natural gas liquefaction plants, large power stations, and major defence acquisition projects such as ships and submarines. Mostly these projects can be positioned within Schumpeter's "circular flow" since they are normally conducted to meet the demand for existing products, and mostly incorporate well-proven technologies.

The success rate of these large-scale engineering projects has declined to about 33% (Merrow 2011) and is still declining.[1] The success criterion adopted by Merrow is that the investors receive at least 50% of the forecast commercial return, a comparatively low bar. Smaller projects (US$100 m – US$1 bn) succeed more often, but

[1] For further information, see articles published at www.ipaglobal.com, such as http://www.ipaglobal.com/new-approaches-to-measuring-engineering-practices

still only about 65% of the time.[2] (Building construction projects are more successful.). Since these projects depend on minimal if any innovation, and rely mainly on similar designs from earlier projects, it can be hard to understand how they could possibly fail.

A surprising proportion of these projects (10–15%) are almost complete failures. One recent example is the Ravensthorpe nickel processing plant in Western Australia conceived in 2004 and expected to cost US$1.4 billion, built for about US$2.6 billion and subsequently sold for US$250 million after the original owners gave up trying to make it work, destroying about $2.4 billion of shareholders' value in the process. Investors are justifiably wary of large engineering projects and company CEOs and senior politicians have expressed strongly critical views of engineers' performance to the first named author during interviews.

By way of further example, in Portugal the national Court of Auditors on analyzing 3266 public works contracts between 2009 and 2013, noted that 1513 contracts with a total value of EUR 4.493 million were executed with either additional or reduced work in relation to that set out in the originally accepted tenders (Tribunal de Contas 2016). The additional work resulted in extra cost to the client (the State) and in the majority of cases examined so did the reduced work due to subsequent court awards. Of the justifications invoked for 57% of the contract alterations, 2474 related to faulty initial project design, the most frequent errors cited being:

- Inadequate forecast of the work necessary for the overall execution of the project.
- Errors in quantity surveying.
- Project design found to be poorly related to the in situ context of application.

Even though technology in most industries is changing, investors tend to prefer well-tested technology, especially in very large projects. Innovation is reduced to a minimum because it is seen as an added element of risk. The very large funding requirements for these projects usually have to be met from risk-averse institutions such as pension funds, so investors want to be assured that all technical elements are well-understood with demonstrated records of success in smaller projects. Why then, is engineering expertise so critical when one might imagine that practically all the detailed plans can be adapted from previous projects? Since all the technologies used in these projects are well-understood, how could the success rate be so low?

Merrow (2011) has identified factors statistically associated with successful large projects, based on correlations using data obtained in about 12,000 projects just before final investment approval and 12–18 months after completion. Yet it is not so clear how these factors play out at the micro level, such as in the day-to-day practices of individual engineers. What is clear is that the success of "ordinary" engineering projects is by no means assured, even when using well-established and tested engineering materials and methods. As demonstrated above, value destruction can amount to several billion dollars in the event of a major project failure.

[2] Merrow, E. Presentation to Engineers Australia, Perth, October 2013.

Each of the projects analyzed by Merrow (2011) employed a large number of engineers. As a rule of thumb, the final investment decision (FID) is made when about 10% of the project cost has been expended and most of the work up until that point requires engineers and others with technical expertise to prepare detailed designs, plans and documents (FEED – Front End Engineering Design) to guide the main implementation or construction phase that follows FID. A large number of engineers (mostly a different population from the ones employed for the FEED phase) will also work on the project during the construction and commissioning stages, and some remain for operations and maintenance.

Therefore, at least from a theoretical perspective, engineers have the opportunity to influence the success of these projects at every stage and help avoid substantial value destruction.

Beyond the statistical correlations identified by Merrow and others, the authors' research on engineering practice reveals several factors likely to influence the success of these large projects.

Let us first consider information represented as plans and drawings. Almost always these define attributes of the end product, the final artefact, and reveal relatively little about how to build it. Even then, the plans and drawings are, in essence, a simplification of reality in many respects. The knowledge of actually building and maintaining artefacts relies extensively on unwritten tacit and implicit knowledge carried in the minds of the people involved, and this knowledge is critical for appropriate interpretation of plans and drawings (Bea 2000; Trevelyan 2014, Chapter 5). As a simple example, in electronic circuit diagrams, the power and ground connections are omitted for clarity. Including them would add visual complexity making the circuit diagram harder to understand. These connections are implied, and often not explicitly specified. Because human interpretation is critical, and no two interpretations are identical, engineers involved in these projects find themselves constantly resolving ambiguities and differences of interpretation, and often forced to make difficult decisions on compromises with uncertain technical implications. Here is a typical example from our data: "Our inspectors rejected a cable installation because the unsupported length of a section of electric power cable was longer than permitted in the relevant standard. However, the local engineers needed help to find an acceptable work-around so the project could comply with standards without unacceptably costly rework." In reality, the physical installation of cables is rarely explicitly specified beyond the provision of cable trays in the structure. Normally, a particular standard will be specified, but this relies on knowledge of the standard among the construction workers which can be tenuous in cases (like this one) where the work is outsourced to a low wage environment in the belief that it can be completed at less cost.

A second factor, as Trevelyan (2014, Chapter 10) explains in a discussion on project management, arises from the fact that current practices are based strongly on the creation of documents, many of which are specified in great detail in publications from organizations such as the Project Management Institute. The meticulously compiled information in these documents, one might assume, should ensure that project work is well coordinated. However, engineers need to appropriate[3] this information because human decisions are based not on written information, but knowledge (true justified beliefs) in the minds of project participants (Trevelyan 2014, Chapter 5; Nonaka 1994). Yet project management texts pay relatively scant attention to the challenges in ensuring that everyone appropriates the information so that they have the knowledge required to make the best possible decisions. Here it should be remembered that engineers make countless instinctive trade-off decisions every day, deciding for example which issues need further investigation and which can be safely deferred, perhaps never to be attended to.

These two factors, interpretation of plans and documents, were selected for the purpose of this discussion from many possible factors. First the need for human interpretation of documents and drawings, interpretations which will necessarily be unique for every person, and second the need for people to appropriate information in order to build knowledge needed for decisions, itself a highly variable and unpredictable process. Both factors illustrate how human differences (in interpretation and learning) will mediate the results of engineering work on any project. Therefore, we have to conclude that engineers must somehow overcome such interpretation and learning differences or else we would not see a significant number of successful projects. In spite of the low performance statistics, many projects do succeed.

There are many techniques adopted by engineers to limit the effects of interpretation and learning differences. From carefully designed organization procedures to technical standards, engineering firms have evolved working methods to constrain the effects of human interpretation differences. Engineers, therefore, bring specialized knowledge which turns out to be of critical importance in what otherwise seems to be dull, boring, routine engineering work with little if any opportunity for technical innovation. By applying these methods, engineers deliver project outcomes that bring use-value to project sponsors: greater predictability of project outcomes (albeit still with significant variability) and hence less incidence of "nasty surprises", unpredictable situations leading to substantial loss of economic exchange-value for sponsors' assets.

An example of the kinds of engineering performance involved in such routine work is provided by Carrasco Torres (2014) who surveyed construction engineering inspection work being outsourced by USA state and federal Transportation Departments. This engineering work was seen as a service in which engineering contractors perform inspection work to provide assurance to their respective employers that the work is being performed economically and satisfactorily with respect to established standards. This service, one can argue, creates use-value in the form of greater reassurance for the highway authorities who no longer have enough of their own engineers to check the work being performed with their money. One can also argue that exchange-value is created because the highway authorities would not be prepared to invest their funds to the same extent without assurances gained through the inspection and monitoring activities of engineers.

[3] Appropriate – the meaning here conveys a form of learning, rather than taking possession of an artefact.

What we see is a pattern in which a large majority of engineers find employment in Schumpeter's circular flow in routine engineering work using well-understood techniques and designs with minimal if any innovation. We have to presume that these engineers are contributing value in the form of what economists term "marginal product": in a relatively unconstrained labor market with adequate supply, remuneration reflects value added. We can be confident that if some firms had discovered that engineers did not add value to company operations, they would have stopped employing engineers. Then, with their profits rising, other firms would quickly find out and follow suit, leading to a collapse in engineering employment. That has clearly not happened. Indeed the Royal Academy of Engineers has expressed concern that the UK will not train enough engineers to meet its needs over the next decade (Kumar et al. 2016, pp. 1, 37, 58).

Let us return to the consideration of large engineering projects once more, knowing that they are not sites for technological innovation. At the final investment decision (FID) one can argue that the exchange-value of the project is equivalent to the amount to be invested. However, given the relatively low chance that a large project will succeed as intended at FID, we can also assert that the likely exchange-value of the project is less than the capital sums set aside by the investors at FID.[4] The value has to be discounted according to the probability of success. In the words of a merchant banker familiar with the success rate of major projects "We always discount engineers' predictions: if they say the rate of return is 20% we will mentally adjust and plan on half that or less." Current success rates would imply that was an optimistic assessment.

Therefore, in the event of a successful project of this kind, one which fulfils investors' expectations created at FID, the exchange-value of the project has been increased by the inverse of the banker's instinctive rate of return discount reported above. With an overall success rate of 33% for large projects, we could argue that the increase in value resulting from successful project delivery could be as much as two thirds of the total investment. Yet, the engineers involved have not contributed to the design (except where needed to rectify errors or omissions left after the FEED team have finished their work), and their work has almost entirely been routine and not innovative. In other words, engineers are creating value in ways not anticipated by the current business value creation literature that focuses entirely on technological innovation. Even if one were to argue that the project value at FID is the sum invested by the project owners, then successful project delivery represents successful *protection* of the original value at FID. Not all projects are successfully delivered so, according to this view, engineers are not always successful in *protecting* the project value created by the FEED activity prior to FID.

[4]The first author interviewed staff from commercial research organizations that provide project owners with independent reviews of such projects. Participants reported that owners exhibit a degree of over-confidence in making decisions to proceed with their projects. Owners tend to discount advice on the likelihood that a project will succeed, assuming that advice from external reviewers on measures needed to address shortcomings is either unduly pessimistic, or will be acted on in the course of the project.

Engineers engaged in operations and maintenance, by the same argument, can also be said to be engaged in *value protection* activity, maintaining an enterprise in a state in which it delivers profits for its owners in line with the original predictions (Orr 1996). According to recent research, even well-managed engineering enterprises are suffering opportunity costs equivalent to 30–50% of turnover due to maintenance and operating mistakes (Hägerby and Johansson 2002). Maintenance is a complex socio-technical activity that is not well researched or understood and improvement efforts by many well-informed organizations have yielded disappointing results, partly due to lack of understanding of these sociological factors (Nair and Trevelyan 2008; Gouws 2014; Gouws and Gouws 2006; Gouws and Trevelyan 2006). For example, a common deficiency in maintenance coordination systems adopted by companies is to record and reward only the performance of maintenance tasks, rather than the quality with which the maintenance task is performed. As in the case of large engineering projects, we can argue that value protection activity by engineers is not guaranteed and it would appear that there could be significant opportunities for improvements with appropriate research-based knowledge (which does not yet appear to be available).

By taking the workplace perspective on value creation through observation of engineers at work, we have seen how engineers create value by, for example, anticipating through design, and later organizing engineering activities in ways that take into account likely variations intrinsic to the nature of human thinking and interpretation and, in doing so, create sufficient value to justify their employment. At the same time, we can see from project performance data that substantial performance improvements from organization changes are at least theoretically feasible. Such organizational changes might, of course, fall under Schumpeter's definition of innovation, especially if the results indicated a large improvement. We can see that many engineers are engaged in *value protection* activity, such that in the absence of their skilled contributions, value would be destroyed.

Therefore, we can conclude that engineers are creating or protecting substantial economic exchange-value, and have the potential to create considerably more by improving the project success performance statistics, all without any need for major technological innovations.

Some of the observations in developing countries by the first author and colleagues (Trevelyan 2014, Chapter 13, 2013; Domal 2010) have provided insights that are relevant in some of the macroeconomic arguments reviewed earlier in the chapter. These insights help identify ways in which engineers can create value, even in much more challenging circumstances than a developed country workplace. Trevelyan (2016) has discussed the issues that motivated these studies of engineering practices in South Asia and Australia, starting with the observation that it seems much more challenging for intelligent and well-educated engineers to provide the kind of reliable, practical and economic results that one could take for granted in Australia for example. Trevelyan (2016) concludes that engineering practice relies on using engineering science in the context of an enterprise that relies on technical collaboration. Engineers aim to maintain sufficient alignment between the interpretations of all the various actors involved with implementing a project and the original technical intentions to ensure that the actual technical and commercial performance provides sufficient benefits to stakeholders to encourage repeat business. While engineering science is universally applicable, technical collaboration is shaped by the social and economic cultures that host the enterprise.

In South Asia, a combination of social-economic, cultural and language barriers combine in ways that make technical collaboration so much more difficult, except in certain enterprises such as telecommunications. Knowledge that is distributed in the minds of the participants (Trevelyan 2014, Chapters 5, 7) is accessed less easily as trust is much harder to establish. For example, even in a large enterprise, the CEO will personally sign every cheque and even senior managers responsible for assets worth hundreds of millions of dollars may have an individual spending authority of less than \$100. As one factory manager explained "I can't even spend enough to bribe the military at the security checkpost down the road to let my trucks pass: I have to give the drivers cash from my own pocket." These and other barriers help to raise the cost of supervision, reducing overall productivity (Trevelyan 2014, Chapters 1, 11, 13).

Public water supplies are a conspicuous example of low productivity: despite dedicated efforts by engineers who acknowledge the critical importance of their work, the water provided through distribution pipes is widely (and rightly) considered to be unsafe to drink. Safe drinking water, therefore, has to be carried, greatly increasing the cost to end-users. These factors contribute large productivity penalties that could be just as important in limiting economic growth as the other factors considered in contemporary macroeconomics.

In the last section of this chapter we will summarize the ways that we have observed engineers creating value. In addition to the well-recognized efficiency improvement and technological innovation contributions we describe four additional value creation mechanisms that play a significant role in the engineering enterprise.

14.4 Value Creation by Engineers

Engineers create value in an engineering enterprise (Trevelyan 2014, Chapter 5) by engaging in several different aspects of engineering work, both as solitary individuals engaged in cognitive tasks such as design and analysis, or through one of many technical collaboration performances (Trevelyan 2014, Chapters 5–12). The first value creation performances fall largely within the technical context of engineering work. When asked, most engineers explain value creation in these terms, and most only described efficiency improvements. Many engineers saw uncertainty reduction as part of their work, yet few were able to describe how uncertainty reductions create value. We identified each of the value creation performances from qualitative analysis of interview transcripts and field observation notes. As explained before, engineers showed little awareness of value creation except from efficiency improvements. We would also argue that many practices adopted by engineers over time, largely as a result of trial and error, evolved precisely because they are more likely to lead to value creation even though the engineers themselves may not typically explain them in these terms.

14.4.1 Value Creation Through Efficiency Gains

In seeking to minimize the human effort, materials, energy, and environmental disturbance required to achieve a specified outcome, engineers are directly creating value even if little or no innovation is required to do that. These efforts reduce the direct cost of the outcome, regardless of whether the cost is measured in economic, environmental or social terms. This can be called "value creation through efficiency improvements" also identified by Zhang and Gregory (2011).

14.4.2 Value Creation by Reducing Technical Uncertainties

By reducing technical uncertainties, engineers reduce the additional human effort, materials, energy and environmental disturbance needed to ensure a given outcome with a given probability of success. This forecast extra provision of human effort, materials, energy and forecast allowance for environmental disturbance is often termed a "design margin", "design factor" or "safety factor". For example, by reducing the additional allowances for uncertainty in the material strength used in a particular component by improvements in the material manufacturing process, engineers can provide assurances about the performance of the component with less material consumption, and hence less energy, human effort and environmental disturbance. Once again, the result is a direct cost reduction. We call this value creation performance "value creation through uncertainty reduction".

14.4.3 Value Creation Through Technical Collaboration and Due Diligence

As explained before, engineers spend much of their time coordinating, inspecting, reviewing and checking technical work performed by others. One way to understand these performances is maintaining the integrity of the technical intentions, in other words aligning actions with intentions. For example, high pressure underwater gas pipelines are expensive yet critical components of an offshore gas production enterprise. With thousands of people involved in making and laying them, there are countless possibilities for mistakes and misunderstandings that could lead to a catastrophic failure with little warning after decades of apparently perfect performance. Therefore, engineers follow a complex series of what Trevelyan (2014) has termed "technical collaboration performances" that form multiple layers of defence to ensure that the original technical intentions are implemented sufficiently well to guarantee the expected level of performance, both technical and commercial.

In a similar way, the engineers and other actors who design and predict the technical and commercial performance of the pipeline are also enacting a complex series of technical collaboration performances. These performances help to eliminate mistakes and misunderstandings that would otherwise compromise the design or lead to false performance expectations. For example, both the project owners and engineers would normally engage independent technical experts to review the design and performance predictions. Collectively these practices are known as "engineering due diligence" and, like the collaboration performances needed for construction, help ensure that the technical intentions are faithfully reflected in the design documentation, project plans and performance predictions.

These human engineering performances create value in two important ways. First, these performances reassure investors that the commercial risks are acceptable, and are sufficiently low to commit the funds and other resources needed to implement the project. A final investment decision (FID) to proceed with a large project depends on creating a high enough level of confidence. In reality, any large engineering project will have to pass several investment decision points (Trevelyan 2014, Chapter 11; Phillips et al. 1999). At each prior decision point, investors have to be satisfied that committing further funding will sufficiently reduce uncertainty in project outcomes. With a given anticipated level of investment return, the value of the project is primarily influenced by the perceived level of risk. By committing funds for further engineering investigation and design work, the perceived level of risk can be reduced and hence the project value increases from an investment perspective. The final investment decision typically requires about 90% of the total project expenditure to be committed, and there is usually no way to recover that expenditure afterwards if the wrong decision is made. Therefore, the knowledge that engineers have exercised due diligence in designing and predicting the technical and commercial performance of the pipeline, and that the engineers who construct and lay the pipeline can guarantee that the expected performance will be realized over a life span of several decades both help to create sufficient investor confidence to commit funding.

Therefore, we can argue that value is being created by engineering performances because the exchange-value of the project, represented by the funding that investors are prepared to make, has increased as a result of those engineering performances. Engineers perform due diligence in order to eliminate as much uncertainty as possible in project outcomes and they quantify any remaining uncertainties. By reducing investors' perceived risks, the exchange value of the project is increased, and hence value is created.

Another group of value creation performances help deliver project outcomes in line with expectations. For example, a gas pipeline that has been designed, laid, commissioned and is ready to transport gas with an expected lifetime of decades is usually worth more than the funding required to design and produce it following the argument already proposed. As explained earlier, we argue that these engineers are engaged in a combination of value creation and value protection performances.

14.4.4 Value Creation and Protection in Maintenance and Operations

Engineers perform value creation and protection work through operations and maintenance activities, both of which require similar elaborate technical collaboration performances by engineers. Again building on the gas pipeline example, without carefully planned and implemented inspections and maintenance, the condition of the pipeline can deteriorate, resulting in considerable value destruction. Accountants use a fixed rate of depreciation as a crude measure of these losses but the rate of depreciation used for accounting purposes is often unrelated to the actual loss of value that depends on how maintenance is actually performed (which is seldom represented adequately by recorded data). For example, an accountant may wish to maximize losses early in the life of a productive asset in order to take advantage of certain taxation rules. A very different strategy is needed to maximize value protection for the physical asset.

14.4.5 Value Creation in Sustainability and Value Co-creation in the Community

A comparatively recent development in engineering practice has been the introduction of comprehensive safety and environmental monitoring practices, largely in response to public concerns following major disasters but also motivated by changing performance expectations among engineers as well. Many engineers find it hard to understand how these practices create value. Once again, the concept of protecting value helps to explain the utility of these practices. In essence, these engineers are creating and maintaining a "social licence to operate" (Trevelyan 2014, Chapter 12; Hardisty 2010) without which a company will either encounter significant regulatory obstacles or worse, face the prospect of being closed down in response to what may be ill-informed community protests. Engineers working on safety and environmental management systems, therefore, can be seen to be enacting value protection performances, even from a narrow enterprise-based perspective. When social and environmental impacts are taken into account, these engineering activities can also be seen in terms of value protection, albeit less easily quantified. These performances can be termed "social licence and sustainability value creation and protection".

Alternatively, following the argument in Sect. 14.3, decreasing the risk of major project delays or premature closure on environmental or social impact grounds results in increased project value for investors.

Recent discussion on value creation and corporate social responsibility has led to the notion of value co-creation. Ironically coming from Michael Porter who has been criticized for a narrow perspective on value creation within a firm, the argument proposes that enterprises can create value both within themselves and the communities in which they operate with appropriate design (Porter and Kramer

2011). This is an extension of Porter's original ideas in which he argued that firms can co-create value both internally and within their buyers' organisations. For example, an appropriately designed product can improve the appearance of the retail outlet in which it is displayed, adding value for the retailer as well as the product manufacturer. While Porter originally argued that this kind of product differentiation can result in higher exchange-value for the product, and hence profits, he has now extended the idea to the community in which the firm operates. He argues that long-term success for an enterprise depends as much on developing the community that hosts an enterprise as it does on the enterprise's own performance. In making this argument, he has opened up further opportunities for engineers to contribute to value creation through practices that have been frequently associated with sustainability or corporate social responsibility.

Ideas associated with value-co-creation may help resolve contradictions alluded to by Eddie Conlon in Chap. 3 and Lovasoa Ramboarisata and Corinne Gendron in Chap. 19. Established practices such as building community respect and a social licence to operate, as well as co-creation of community value motivated by a more far-sighted attitude to enterprise success from a corporate social responsibility perspective could form part of such a resolution.

14.4.6 Value Creation Through Innovation, Research and Development

Finally, engineers create value through the well-acknowledged innovation activities such as research, development, experimentation, and intellectual property protection.

This process is exemplified by the far from exhaustive list in Table 14.1 of innovations by US small firms in the twentieth century:

14.4.7 Global Value Creation Model

In summary, therefore, we are proposing a model of engineering value creation and protection. Engineers create value by:

1. Efficiency improvements, enabling a given outcome to be achieved with less human effort, material and energy consumption, and environmental and social disruption; such improvements may involve new disruptive processes or technology as in the forms of innovation envisaged by Schumpeter, but in many cases may simply amount to indivisible incremental improvements: innovation is not necessary;
2. Technical and commercial uncertainty reduction, enabling smaller performance margins to guarantee performance expectations;

Table 14.1 US small business administration, the state of small business: a report of the president, 1995 Washington DC, US Government Printing Office, 1995, p. 114

Innovations by US small firms in the twentieth century		
Air conditioning	Heart valve	Photo typesetting
Aeroplane	Helicopter	Polaroid camera
Assembly line	High resolution CAT scanner	Portable computer
Audio tape recorder	Human growth hormone	Prefabricated housing
Photosynthetic insulin	Hydraulic brake	Quick-frozen food
Catalytic cracking	Integrated circuit	Safety razor
Cotton picker	Microprocessor	Soft contact lens
Defibrillator	Nuclear magnetic resonance	Solid-fuel rocket engine
DNA fingerprinting	Optical scanner	Vacuum tube
Electronic spreadsheet	Oral contraceptives	Xerography
FM radio	Pacemaker	X-Ray telescope
Geodesic dome	Personal computer	Zip fastener
Gyrocompass	Pacemaker	

3. By exercising engineering due diligence via technical collaboration performances, engineers reduce the actual and apparent risks for investors, and in doing so increase the exchange-value of prospective engineering ventures. Likewise through due diligence in technical collaboration performances, engineers deliver projects and operating results in line with expectations, and both protect existing value and create additional enterprise value by doing so;
4. Furthermore through operations and maintenance work, engineers create and protect value created earlier, thus helping to prevent value destruction in the enterprise, the environment and in communities that host the enterprises;
5. Through appropriate design, planning, organization and collaboration performances, engineers can help create value in the form of a social licence to operate and can co-create value both in their own enterprises and in the communities that host them.
6. As described in the existing literature, engineers contribute value through research, development and innovation, and intellectual property protection.

From our research, we can confidently report that elements 2, 3, 4 and 5 in this model are not well understood by engineers today. Given that engineers are relatively autonomous in their work, value perceptions are likely to influence countless instinctive decisions that engineers make every day, often involving perceived value trade-offs. For example, observations have shown that engineers relegate[5] checking and review work because they think that design and calculation work is more productive (Mehravari 2007; Trevelyan 2010). In reality, however, checking and review work creates value by reducing uncertainties and reducing investors' risk perceptions, thereby increasing the exchange value of a project.

[5] Meaning to assign an inferior value

Here we should heed Ng et al. (2010): use-value is co-created by the beneficiaries on accepting the provider's value proposition. Creation and protection of use-value thus depend very much on how the beneficiaries (clients, owners, end-users, communities, societies) experience the results of engineering performances. Therefore, engineers need to design products and services in a way that enables the beneficiaries to experience the full potential use-value anticipated at the time of exchange or purchase.

We could also note that value creation and protection concepts can be applied in production of defence equipment and services, even if they are never used in an actual conflict. Our research revealed that defence engineers found it even more difficult to articulate the value of their contributions than civilian engineers. Use-value of defence equipment and services can be perceived in three ways. First they have deterrent value reducing the likelihood of destruction caused by actual conflict. Second, good defence equipment limits destructive behavior and reduces the extent of destruction sustained. Finally, use-value can be perceived as "a feeling of security" or "peace of mind" similar to an insurance policy.

14.5 Limitations

We acknowledge that many of the examples provided have been drawn from large-scale high-investment projects. The authors' studies of smaller enterprises and SMEs suggest that similar factors are at play but this warrants more research.

14.6 Conclusions and Implications

In this chapter we have attempted to explain how engineers engage in value creation and value protection within an engineering enterprise, a business venture that depends for its success on the application of specialized engineering knowledge. In doing so, we expand on the tenuous ideas available from the literature analyzed at the start of this chapter which tends to locate engineering value creation in engineering in terms of technological innovation activity in which a minority of engineers participate. Perhaps it is this lack of written explanation that leads to the different perspectives from within engineering and business schools that Michael Davis has drawn our attention to in the opening Chap. 2 "The Odd Couple".

There are some unfortunate consequences that result from the paucity of writing on this subject, and the resultant notion that technological innovation is the major source of engineering value creation.

First, because discussions on engineering value creation have focused almost entirely on technological innovation, many engineers who are not involved with technically innovative work fail to appreciate how their work creates or protects value. Instinctively they devalue other kinds of engineering performances, and their own status as a result. For example, engineers do not like to be involved with maintenance work: it is seen as a low-status engineering role. This helps to explain a prominent movement among maintenance engineers since the 1990s to portray their work as "asset management" instead of "maintenance". Unfortunately these efforts have not made much impact, partly because the term "asset management" is more widely known in the finance industry as an investment management activity. Understanding how, for example, reusing a well-established design or improving maintenance effectiveness creates commercial value could help engineers better understand the significance of their work and argue more effectively for appropriate resources. Being able to understand their work in terms of value protection could help counter the common business view of maintenance as merely a "cost centre", resolving a common frustration encountered by many maintenance engineers (Gouws 2014).

Second, the resulting misalignment between engineers' and investors' ideas on value creation leads to frustration on both sides. Engineers find it hard to understand decisions by investors and investors display similar frustrations with engineers, accusing some of "excessive gold-plating". A better understanding of engineering value creation could help young engineers in their early careers, and ease the present tensions evident in many engineering enterprises between managers and their engineers. Chapter 16 by Russell Korte and Chap. 22 by Anette Kolmos and Jette Egelund Holgaard discuss the graduate engineer's transition from education to workplace in more detail.

Third, data show that engineers' value creation and protection performances in respect of categories 2, 3, 4 and 5 above are unsatisfactory and can fall far short of reasonable expectations. Given that few engineers appreciate the value creation and protection resulting from these activities, it is not surprising to find evidence pointing to large potential performance improvements.

Fourth, and potentially more serious in terms of future engineering performance, are weaknesses in engineering education that reflect current understandings on value creation: in engineering, according to this understanding, value is only created through technological innovation. In technical courses, technical innovation is highly valued, particularly since individual teaching academics are rewarded for research innovations that are primarily technical in nature. This emphasis reflects the prevailing Schumpeterian view that value is created through innovations, and technical innovation therefore is the way that engineers create value. Potentially large performance improvements are possible and, given the significance of engineering activities in both developing and developed economies, the possibility for significant effects on productivity improvement and economic growth cannot be ruled out.

We began the chapter by highlighting the predominant view that considers use and exchange value creation by engineers as being innovation-based, and we went on to show how the circular flow concept from Schumpeter's writings helps to identify four additional value creation mechanisms in engineering enterprises. We believe this analysis provides insights that are of considerable importance for both engineering practitioners and educators. In addition we suggest that research into the precise mechanisms of these little-studied value creation activities could potentially result in significant savings in large-scale engineering projects.

In the light of research on engineering practice that demonstrates how engineers are creating new value and protecting established value, the ardent efforts by those promoting entrepreneurship education under the Schumpeterian model that privileges technological innovation may well be misplaced. We are not arguing here that Schumpeter was mistaken. However, in the comparative absence of understanding on engineering practice, even among engineers, business researchers can be forgiven for overlooking ways in which engineers create and protect value. Perhaps, with the help of the research results described in this chapter, the scope of entrepreneurship education in engineering faculties could be broadened to help all engineering students understand how they can create and protect value in a variety of career settings, not just fragile and vulnerable technology start-ups. Is it surprising, therefore, that engineers' current performance weaknesses lie in precisely the aspects of performance that are neither currently valued nor taught?

Finally, the argument in this paper helps to demonstrate that the value contributed in an economy by engineers is likely to be much larger than is currently appreciated, even by engineering advocacy organizations. It is imperative that the potential for large engineering performance improvements, and hence large macroeconomic improvements in both developing and developed economies, be brought to the attention of policymakers. Engineering educators and firms could use this argument to justify significant government investment to improve education programs for engineers.

Acknowledgements The authors wish to acknowledge the willing participation of engineering practitioners in Australia, Pakistan, India and Portugal in providing data for our studies and we hope to have done justice to the trust they extended by inviting us into their workplaces and taking time to share their work practices with us. Funding from the Australian government and the Portuguese Fundação para a Ciência e a Tecnologia supported studies by the authors that provided much of the data for this chapter.

References

Ács, Z. J. (2010). Entrepreneurship and economic development: The valley of backwardness. *Annals of Innovation and Entrepreneurship, 1*(1). https://doi.org/10.3402/aie.v1i15641.

Ács, Z. J., Autio, E., & Szerb, L. (2014). National Systems of Entrepreneurship: Measurement issues and policy implications. *Research Policy, 43*(3), 476–494. https://doi.org/10.1016/j.respol.2013.08.016.

Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal, 31*, 306–333. https://doi.org/10.1002/smj.821.

Amit, R., & Zott, C. (2001). Value creation in E-business. *Strategic Management Journal, 22*, 493–520. https://doi.org/10.1002/smj.187.

Barley, S. R. (2005). What we know (and mostly don't know) about technical work. In S. Ackroyd, R. Batt, P. Thompson, & P. S. Tolbert (Eds.), *The Oxford handbook of work and organization* (pp. 376–403). Oxford: Oxford University Press.

Baumol, W. J. (1990). Entrepreneurship: Productive, unproductive and destructive. *Political Economy, 98*(5 part 1), 893–921.

Bea, R. (2000). Human and organizational factors in the design and reliability of offshore structures. PhD, Centre for Oil and Gas Engineering, The University of Western Australia.

Besterfield-Sacre, M. E., Ozaltin, N. O., Robinson, A., Shuman, L. J., Shartrand, A., & Weilerstein, P. (2013). Factors related to entrepreneurial knowledge in the engineering curriculum. *Journal of Engineering Entrepreneurship, 4*(1), 31–38 https://doi.org/10.7814/jeen5v4p3borssw.

Besterfield-Sacre, M. E., Zappe, S. E., Shartrand, A., & Hochstedt, K. (2016). Faculty and student perceptions of the content of entrepreneurship courses in engineering education. *Advances in Engineering Education, 5*(1), P4.

Bhutta, Z. A. (2011). *Pakistan national nutrition survey*. Karachi: Aga Khan University https://www.humanitarianresponse.info/system/files/documents/files/59_National%20Nutrition%20Survey-2011.pdf. Accessed 1 May 2016.

Boyd, T. (2013). Still lucky, but useless at settling projects. *Australian Financial Review*, p 1.

Carlson, W. B. (1988). Academic entrepreneurship and engineering education: Dugald C. Jackson and the MIT-GE cooperative engineering course, 1907–1932. *Technology and Culture*, *29* (3), 536–567. 0040-165X/88/2903-0006.

Carrasco Torres, V. (2014). Evaluation of highway agency approaches to consultant oversight for construction engineering and inspection services. Master of Civil Engineering Masteri of Civil Engineering, Civil Engineering, University of Colorado.

Costa, C., & Baptista, R. (2012). The molds cluster in Portugal. *CEG-IST Working Paper*. 42.

Creed, C. J., Suuberg, E. M., & Crawford, G. P. (2002). Engineering entrepreneurship: An example of a paradigm shift in engineering education. *Journal of Engineering Education, 91*(2), 185–195. https://doi.org/10.1002/j.2168-9830.2002.tb00691.x.

Crossley, M. (2011). Business skills in engineering practice. Bachelor of Engineering, School of Mechanical Engineering, The University of Western Australia.

D'Arcy, P., & Gustafsson, L. (2012). Australia's productivity performance and real incomes. *Reserve Bank of Australia Bulletin (June Quarter)*, 23–35.

Dolphin, T., & Hatfield, I. (2015). *The missing pieces: Solving Britain's productivity puzzle*. London: Institute for Public Policy Research http://www.ippr.org/publications/the-missing-pieces-solving-the-uks-productivity-puzzle.

Domal, V. (2010). Comparing engineering practice in South Asia and Australia. PhD thesis, Mechanical and Chemical Engineering, The University of Western Australia.

Duval-Couetil, N. (2013). Assessing the impact of entrepreneurship education programs: Challenges and approaches. *Journal of Small Business Management, 51*(3), 394–409. https://doi.org/10.1111/jsbm.12024.

Finelli, C. J., Borrego, M., & Rasoulifar, G. (2015). Development of a taxonomy of keywords for engineering education research. *Journal of Engineering Education, 104*(4), 365–387. https://doi.org/10.1002/jee.20101.

Franke, N., & Piller, F. (2004). Value creation by toolkits for user innovation and design: The case of the watch market. *Journal of Product Innovation Management, 21*, 401–415. https://doi.org/10.1111/j.0737-6782.2004.00094.x.

Gilbuena, D. M., Sherrett, B. U., Gummer, E. S., Champagne, A. B., & Koretsky, M. D. (2015). Feedbackon professional skills as enculturation into communities of practice. *Journal of Engineering Education, 104*(1), 7–34. https://doi.org/10.1002/jee.20061.

Gouws, L. (2014). The extent and nature of problems encountered in maintenance: The story behind the text. PhD thesis, Mechanical and Chemical Engineering, The University of Western Australia.

Gouws, L., & Gouws, J. (2006). Common pitfalls with SAP™-based plant maintenance systems. 2006 world congress on engineering asset management, Surfer's Paradise, Queensland, 10–14 July.

Gouws, L., & Trevelyan, J.P. (2006). Research on influences on maintenance management effectiveness. 2006 world conference on engineering asset management, Surfer's Paradise, Queensland, 10–14 July.

Hägerby, M., & Johansson, M. (2002). Maintenance performance assessment: Strategies and indicators. MSc, Department of Production Economics, Linköping Institute of Technology.

Hardisty, P. E. (2010). Environmental and economic austainability. In M. C. Newman (Ed.), *Environmental and ecological risk assessment*. Boca Raton: CRC – Taylor & Francis.

Jacobides, M. G., Knudsen, T., & Augier, M. (2006). Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. *Research Policy, 35*, 1200–1221. https://doi.org/10.1016/j.respol.2006.09.005.

Jensen, J. S., & Jørgensen, U. (2018). *Valuation and market creation: The economic dynamics of socio-material*. Unpublished manuscript, personal communication available on Request.

Katz, J. A. (2003). The chronology and intellectual trajectory of American entrepreneurship education. *Journal of Business Venturing, 18*, 283–300. https://doi.org/10.1016/S0883-9026(02)00098-8.

Kelm, K. M., & Narayanan, V. K. (1995). Shareholder value creation during R&D innovation and commercialization stages. *Academy of Management Journal, 38*(3), 770–786.

Köbler, F., Fähling, J., Vattai, A., Leimeister, J.M., & Kremar, H. (2009). Analysis of value creation through product-service-systems in the German medical engineering industry. First International Symposium of Service Sciences 2009 (ISSS 2009), Berlin.

Kohers, N., & Kohers, T. (2000). The value creation potential of high-tech mergers. *Financial Analysts Journal, 56*(3), 40–50. https://doi.org/10.2469/faj.v56.n3.2359.

Kumar, A., Moss, A., & Johnson, E. (2016). *Engineering UK 2016: The state of engineering*. London: Engineering UK Accessed 29 Apr 2016.

Lavie, D. (2007). Alliance portfolios and firm performance: A study of value creation and appropriation in the US software industry. *Strategic Management Journal, 28*, 1187–1212. https://doi.org/10.1002/smj.637.

Manyika, J., Woetzel, J., Dobbs, R., Remes, J., Labaye, E., & Jordan, A. (2015). *Global growth: Can productivity save the day in an aging world?* London: McKinsey Global Institute http://www.mckinsey.com/mgi. Accessed 1 May 2016.

McNair, C. J., Polutnik, L., & Silvi, R. (2001). Cost management and value creation: The missing link. *European Accounting Review, 10*(1), 33–50. https://doi.org/10.1080/09638180122848.

Mehravari, D. (2007). Systematic checking in engineering design. Bachelor of Engineering, School of Mechanical Engineering, The University of Western Australia.

Merrow, E. W. (2011). *Industrial megaprojects: Concepts, strategies, and practices for success*. New Jersey: Wiley.

Mizik, N., & Jacobson, R. (2003). Trading off between value creation and value appropriation: The financial implications of shifts in strategic emphasis. *Journal of Marketing Education, 67*(1), 63–76.

Moore, S. B., & Manring, S. L. (2009). Strategy development in small and medium sized enterprises for sustainability and increased value creation. *Journal of Cleaner Production, 17*, 276–282. https://doi.org/10.1016/j.jclepro.2008.06.004.

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1993). Why is rent-seeking so costly to growth? *American Economic Association Proceedings, 83*(2), 409–414.

Nair, S., & Trevelyan, J.P. (2008). Current maintenance management methods cannot solve engineering asset maintenance history data quality problems. ICOMS Asset Management Conference, Fremantle, Western Australia, May 27–29.

Ng, I.C.L., Parry, G., Smith, L.A., & Maull, R.S. (2010). Value co-creation in complex engineering service systems: Conceptual foundations. In *Forum markets and marketing: Extending the service dominant logic*. University of Exeter Business School Discussion Papers in Management 10/04.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science, 5*(1), 14–37. https://doi.org/10.1287/orsc.5.1.14.

Orr, J. (1996). Talking about machines: An ethnography of a modern job. In S. Barley (Ed.), *Collection on technology and work*. Ithaca: Cornell University Press.

Pessôa, M.V.P., Loureiro, G., & Alves, J.M. (2006). A value creation planning method to complex engineering products development. 13th ISPE International Conference on concurrent engineering: Research and applications. Antibes.

Phillips, R., Neailey, K., & Broughton, T. (1999). A comparative study of six stage-gate approaches to product development. *Integrated Manufacturing Systems, 10*(5), 289–297.

Porter, M. E. (1985). *Competitive advantage: creating and sustaining superior performance*. New York: Free Press.

Porter, M.E., & Kramer, M.R. (2011). Creating shared value. *Harvard Business Review*, 15.

Porter, M. E., Sachs, J., & McArthur, J. W. (2002). Executive summary: Competitiveness and stages of economic development. In K. Schwab, M. E. Porter, & J. Sachs (Eds.), *The global competitiveness report 2001–2002*. New York: Oxford University Press.

Quinlan, K. M. (2002). Scholarly dimensions of academics' beliefs about engineering education. *Teachers & Teaching: Theory and Practice, 8*(1), 41–64. https://doi.org/10.1080/13540600120110565.

Rankin, Y.A., Boyette, N.H., Cheng, I.K., & Krishna, V. (2009). The pursuit of value Co-creation: Engineering service applications to achieve customer satisfaction. IEEE/INFORMS Conference on Service Operations, Logistics and Informatics, 2009. SOLI '09., Chicago, 22–24 July.

Romer, P. (1990). Endogenous technological change. *Political Economy, 98*(5 part 2), S71–S102.

Romer, P. (2010). Which parts of globalization matter for catch-up growth? *NBER Working Paper, 15755*, 15.

Schumpeter, J. (1911:1934). *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Translated from the 1911 original German, heorie der wirtschaftlichen Entwicklung*. Cambridge, MA: Harvard University Press.

Schumpeter, J. (1942, 1950). *Capitalism, socialism and democracy*. New York: Harper & Row.

Shimomura, Y., Sakao, T., Sundin E., & Lindahl, M. (2006). Service engineering: A novel engineering discipline for high added value creation. International Design Conference – Design 2006, Dubrovnik, Croatia, 15–18 May.

Singh, R. (2015). How do engineers perceive the notion of value: A discussion of value in engineering practice? Bachelor of Engineering, School of Mechanical Engineering, The University of Western Australia.

Sköld, D., & Olaison, L. (2012). Excessive value creation: Under the tyranny of a new imaginary. In D. Jemielniak & A. Marks (Eds.), *Managing dynamic technology-oriented businesses: High tech organizations and workplaces* (pp. 192–208). Hershey: IGI Global.

Trevelyan, J. P. (2007). Technical coordination in engineering practice. *Journal of Engineering Education, 96*(3), 191–204.

Trevelyan, J. P. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175–195. https://doi.org/10.1080/19378629.2010.520135.

Trevelyan, J.P. (2012). Understandings of value in engineering practice. Frontiers in Education 2012, Seattle.

Trevelyan, J. P. (2013). Observations of South Asian engineering practice. In B. Williams, J. D. Figueiredo, & J. P. Trevelyan (Eds.), *Engineering practice in a global context: Understanding the technical and the social* (pp. 223–244). Leiden: CRC/Balkema.

Trevelyan, J. P. (2014). *The making of an expert engineer*. London: CRC Press/Balkema – Taylor & Francis.

Trevelyan, J. P. (2016). Extending engineering practice research with shared qualitative data. *Advances in Engineering Education, 5*(2), 31 http://advances.asee.org/publication/extending-engineeringpractice-research-with-shared-qualitative-data/.

Trevelyan, J. P., & Tilli, S. (2007). Published research on engineering work. *Journal of Professional Issues in Engineering Education and Practice, 133*(4), 300–307. https://doi.org/10.1061/(ASCE)1052-3928(2007)133:4(300).

Trevelyan, J.P., & Tilli, S. (2008). Longitudinal study of Australian engineering graduates: Perceptions of working time. American Society for Engineering Education Annual Conference, Pittsburgh, June 20–22.

Tribunal de contas (2016). Relatório n.° 1/2016 – AUDIT. 1.ª S., Tribual de Contas, Lisboa, 2016. Accessed 17 Nov 2016. http://www.tcontas.pt/pt/actos/rel_auditoria/2016/1s/rel001-2016-1s.pdf.

Walter, A., Ritter, T., & Gemünden, H. G. (2001). Value creation in buyer-seller relationships: theoretical considerations and empirical results from a supplier's perspective. *Industrial Marketing Management, 30*, 365–377.

Williams, B., & Figueiredo, J. (2015). Interaction in the engineering workplace: Examining a network of actors representation. 2015 IEEE International Conference on Engineering, Technology and Innovation/ International Technology Management Conference (ICE/ITMC), Belfast, 22–24 June.

World Bank (2016). Data on agricultural employment. Accessed 1 May. http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS.

Yannou, B., & Bigand, M. (2006). A curriculum of value creation and management in engineering. *European Journal of Engineering Education, 29*(3), 355–366. https://doi.org/10.1080/03043790310001658550.

Youngman, M., Oxtoby, R., Monk, J. D., & Heywood, J. (1978). *Analysing jobs*. Farnborough: Gower Press.

Zhang, Y., & Gregory, M. (2011). Managing global network operations along the engineering value chain. *International Journal of Operations and Production Management, 31*(7), 736–764. https://doi.org/10.1108/01443571111144832.

Zhu, K., Kraemer, K. L., Xu, S., & Dedrick, J. (2004). Information technology payoff in e-business environments: An International perspective on value creation of e-business in the financial services industry. *Journal of Management Information Systems, 21*(1), 17–54.

James Trevelyan Emeritus Professor, engineer, educator and researcher with 45 years of experience, became a start-up entrepreneur in 2015. He leads Close Comfort, introducing new energy saving air conditioning technology to Pakistan and other countries. He taught design, computer methods, project management and sustainability at The University of Western Australia, one of the world's top 100 universities. He is best known internationally for pioneering research that resulted in sheep shearing robots and for the first industrial robot that could be remotely operated via the internet in 1994. He has received international awards for robotics research and engineering education. He also researched landmine clearance methods. In 2002, he was elected a Fellow of Engineers Australia and started researching engineering practice, what engineers really do in their work. He built on this research to design the current Australian stage 2 professional engineering competencies for engineers, technologists and associates. His 2014 book *The Making of an Expert Engineer* provides, for the first time, a comprehensive research-based understanding of engineering practice in several countries. It explains why engineered products and services are usually far more expensive in developing countries than the industrialized world, which in turn explains why so many people continue to live in stubbornly persistent poverty.

Bill Williams Originally trained as a chemist at the National University of Ireland and went on to work in education in Ireland, UK, Eritrea, Kenya, Mozambique and Portugal and to run international distance courses for the International Labour Organization in various African countries. He is a member of the Centre for Management Studies (CEG-IST) of Instituto Superior Técnico, Universidade de Lisboa, Portugal and Adjunct Senior Research Fellow at the Dublin Institute of Technology (DIT), Ireland . His research interests include engineering practice and the global evolution of engineering education research. He is lead editor of the edited volume Engineering Practice in a Global Context, Understanding the Technical and the Social published by Taylor and Francis in 2013 and is a member of the Review Committee of the Taxonomy of Engineering

Education Research. Bill Williams is an associate editor of the Journal of Engineering Education and of the European Journal of Engineering Education, member of the Board of the Working Group on Engineering Education Research of SEFI and is a founder member of the Portuguese Society for Engineering Education (SPEE).

Chapter 15
Eliminating Gender Inequality in Engineering, Industry, and Academia

Jane Grimson and William Grimson

Abstract Gender equality in the workplace with its many facets is a current topic of great interest in many societies and across virtually all sectors. Women are seriously under-represented in senior positions within organizations and there is evidence of a continuing pay gap between women and men. Industry, commerce, business, law, medicine, engineering, academia all have responded to or are responding to the challenges of eliminating gender inequality. There are three specific reasons for this. The first is based on the principle that there is or should be a prevailing environment guaranteeing social justice and human rights for all. The second is in effect a question of parsimony by which talent should not be wasted. Finally, and the imperative for the elimination of gender inequality which is receiving the most attention today, is that of diversity. The diversity argument adds to the 'not being wasteful' by virtue of the range of different skills, perspectives and experiences that are brought to bear on whatever challenge is being faced. Tackling gender equality is a complex task requiring many interventions but what is clear is that there is broad agreement across the different sectors, including engineering, as to what is required. The key interventions include committed and determined leadership from the top of the organization over a sustained period of time, supports to ensure better work-life balance, developing future women leaders, and tackling unconscious bias. The evidence is unequivocal – gender balance will not be achieved automatically without a range of such interventions and failure to take action will have a major impact on the engineering profession's ability to meet the needs of society today and tomorrow.

Keywords Gender (in)equality · Unconscious bias · Work-life balance · Diversity · Leadership

---

J. Grimson (✉)
School of Computer Science and Statistics, Trinity College Dublin, Dublin, Ireland
e-mail: jane.grimson@tcd.ie

W. Grimson
Dublin Institute of Technology, Dublin, Ireland
e-mail: william.grimson@dit.ie

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_15

Women hold up half the sky (Mao Zedong)

15.1 Introduction

There are many views as to how we should live and organize ourselves on our planet Earth varying from a 'back to nature' idealism to a futuristic technology-dominated world. For the moment, though, we inhabit a middle ground where we strive to maintain a balance between the extremes. Global healthcare and climate change are just two of the many challenges that face humanity. To address these and other challenges, engineering needs to be to the fore in providing solutions. The United States National Academy of Engineering has expressed the view that:

> No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people's everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century. (National Academy of Engineering 2008)

Two immediate questions arise: first, are there a sufficient number of engineers to meet these aspirations, and second, avoiding the perils of groupthink and over reliance on prevailing orthodoxies, is there sufficient diversity amongst the engineering community to ensure robust, sustainable solutions are found that meet the needs of all in society? Regarding the first question, most countries report a shortage of engineers to support existing conditions let alone 'engineer' the future. But it is the second question with which this chapter is concerned. Though diversity has multiple degrees (ethnic, geographical, age, to list just three) it is gender that is in focus here. And further, a simple male-female perspective is taken, though an extension to a more nuanced one is not difficult to imagine.

Engineering has been and remains a largely male-dominated field. In the US, women comprise only 12% of the engineering workforce[1]; in the UK the figure is 9%,[2] the lowest in Europe (VDI 2010). In general, the highest proportion of female engineers is to be found in Eastern European countries such as Latvia and Bulgaria at 30%. These figures, of course, reflect the relatively low numbers of women entering the engineering profession. In the USA the percentage of bachelor degrees in engineering awarded to women increased steadily from 0.4% in 1966 to a peak of 20.9% in 2002, and then dropped off slightly to just under 20% in 2014.[3] In the UK the percentage of female engineering graduates rose from 7% in 1984[4] to 15% in 2014 (Engineering UK 2016). Thus the numbers entering the pipeline, i.e. completing engineering degrees, has been increasing slowly over the past 30 years to an

[1] http://www.aauw.org/research/solving-the-equation/

[2] http://www.wes.org.uk/content/useful-statistics

[3] https://nsf.gov/statistics/2017/nsf17310/digest/fod-women/engineering.cfm

[4] http://www.wes.org.uk/content/useful-statistics

average of 15–20% globally, depending on the branch of engineering with up to 50% in bioengineering. But even if all these women continue in engineering careers, it will take many, many decades before women reach 30% of the engineering workforce, regarded as the tipping point to change the culture.[5]

This chapter examines why women continue to be significantly under-represented in senior position in engineering, why it is important to address the issue, and discusses a number of measures which organizations are taking to address this leaky pipeline. Two case studies are presented – one from academia and one from industry. Since the under-representation of women in senior positions is a common feature in a number of other professions and sectors, the chapter draws on evidence from outside as well as inside engineering – and many of the actions proposed have wide applicability.

15.2 Why Gender Inequality Persists

Equality legislation has ensured that the amount of overt or conscious gender-based discrimination against women has been significantly reduced and the importance of promoting greater gender equality especially at senior levels within organizations is widely recognized and acknowledged. The business case, at least in the corporate world, is increasingly at the heart of corporate strategy. In academia it has long been recognized that women do not progress to senior leadership positions and full professorships in the same proportion as their male colleagues and indeed in proportion to their representation at the lower grades. Only 20% of higher education institutions were headed by a woman across the EU in 2015 (Portia 2015) and only 14% of the top universities globally (Bothwell 2015). Figure 15.1 shows that in 2014 while women outnumbered men at undergraduate level across the EU universities (55%), they comprised only 21% of full professors (Grade A).

While similar graphs of the "leaky pipeline" are not available for industry, it is clear from the data that is available, the picture is similar. Although in engineering, it should be noted that the lines do not actually intersect as the number of male undergraduates continue to significantly exceed the number of female undergraduates. Even though the number of women entering the engineering career pipeline are small, their numbers at senior management and director level (which can be thought of as equivalent to Grade A professors) are proportionately much less than the number of men.

The lack of women in senior leadership positions in engineering suggests that there is a retention issue. Are women with a primary engineering qualification less likely to enter the profession or, if they do, do they stay and progress to leadership positions? There are two key studies which can help to answer this question. The first is a study which was conducted by the Royal Society of Edinburgh (2012) *Tapping all our Talents*. It concluded that while 48% of men with Science,

[5] https://30percentclub.org/resources/faqs

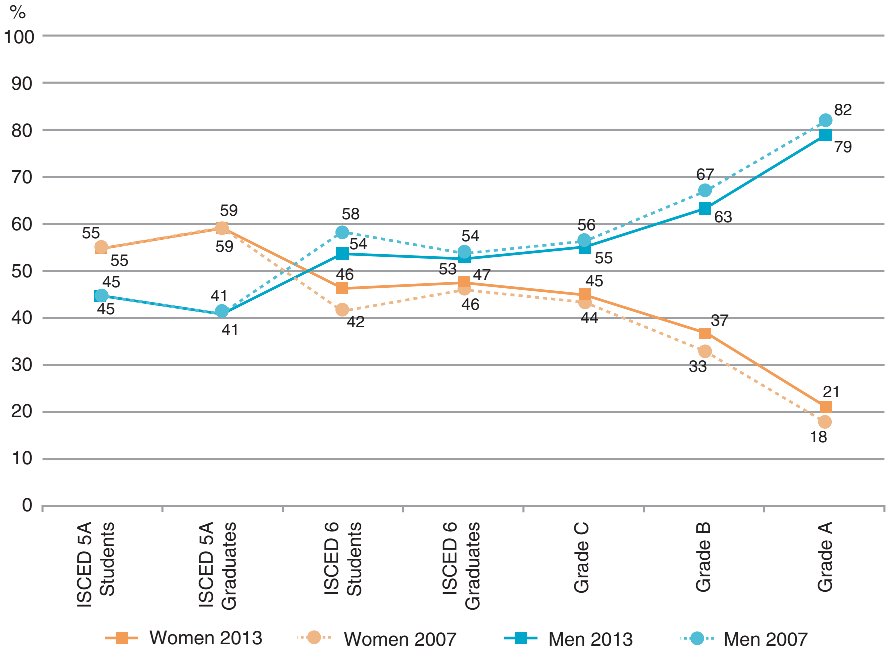

Fig. 15.1 Proportion of men and women in a typical academic career, students and academic staff, EU-28, 2007–2013. (Source: European Commission DG for Research and Innovation [Source: European Commission 2016])

Technology, Engineering and Mathematics (STEM) qualifications did not progress to careers in STEM, the corresponding figure for women is 73%. A US study indicated that the retention of women in engineering appeared to be better than other STEM areas but 40% of women engineering graduates either left the profession early on, or else never entered it in the first place (Sibley 2016). Both reports concluded that the traditionally male culture in which women may feel under-valued, over-looked or assigned to less technical tasks within engineering represents a major contributory factor to this loss of talent.

Given that far fewer women than men enter the engineering profession and that there appears to be a problem retaining women in engineering careers, it is not surprising that only a few are reaching the top of their organization in senior management and leadership positions. The reasons are complex and multi-factorial, and therefore so is the solution (Grimson and Roughneen 2009). Rather than a single major barrier halting or delaying their career progress, women are faced with a series of small barriers or hurdles which in combination act cumulatively to disadvantage women (MIT 1999). Or to put it more simply *"Many molehills make a mountain"* (Valian 1999).

Following the introduction of equality legislation, the emphasis was on initiatives which aimed to "fix the women" with a view effectively to supporting them to conform to the male norm. Under the "fix the women" or deficit model it is women who are seen as the problem. They are blamed for "lack of career planning, low self-esteem, lack of career ambition, poor political skills, poor ability to market themselves and lifestyle choice" (O'Connor 2014:107–108). Today, the emphasis is moving increasingly to initiatives which seek to "fix the system" and change the culture to one that is inclusive and values diversity. Such initiatives recognize the fact that gender equality and diversity generally offer benefits not only to women/minorities but also critically both to all employees and to the organization itself. Under the "fix the system" it is about transforming the organization to be inclusive.

15.3 The Gender Equality Imperative

The under-representation of women in certain professions, including engineering, and in particular their low representation in leadership roles has become a topic of major strategic importance at the level of the individual organization, nationally and internationally. The arguments for addressing the issue fall into three inter-related areas:

- Human rights/social justice
- Talent
- Diversity

15.3.1 Human Rights/Social Justice

The human rights/social justice arguments in favor of greater gender equality have been at the heart of government policies in most countries for many, many years. They encapsulate the principles that all careers should be open to both women and men on an equal basis and that there should be equal pay for equal work. Equality legislation banning discrimination on the basis of gender and providing for equal pay has been in place for decades in most countries. For example, the Equal Pay Act was introduced in the UK in 1970 and the Sex Discrimination Act in 1975. In 2006, the European Union consolidated previous Directives in the area of anti-discrimination in the Equal Treatment Directive 2006/54/EC (European Commission 2006).

As well as the legal imperative for equality, social justice/human rights/ethical considerations demand that all careers should be open to both women and men and both women and men can expect to be supported in developing their careers. In spite of this, however, cases of discrimination on grounds of gender continue to be taken by women and won against organizations (European Commission 2010).

The gender pay gap continues to be an issue internationally. A recent report from the European Commission found that on average women earned 16% less than men (European Commission 2014). Viviane Reding, Former EU Justice Commissioner, summed up the situation on European Equal Pay Day – February 28 2014:

> Equal pay for equal work is a founding principle of the European Union, but sadly is still not yet a reality for women in Europe. (Perrons 2015)

However, there is no doubt that the situation has improved dramatically since the time when many countries had a marriage bar in place, which effectively meant that women had to resign once they got married and married women could not be employed (there were of course exceptions!). In the UK, the ban was lifted in 1946, in Ireland in 1973 and in the Netherlands in 1975. The marriage bar reflected the widely held societal belief that a woman's place was in the home. This was perhaps no more clearly demonstrated when after the First World War, the UK's Restoration of Pre-War Practices Act (1999) required that the women who had played such a vital role in the war effort be dismissed to make way for the returning men. Katherine Parsons, wife of Charles Parsons, the inventor of the steam turbine, complained (Scaife 2000):

> It has been a strange perversion of women's sphere – to make them work at producing the implements of war and destruction, and to deny them the privilege of fashioning munitions of peace...women are merely told to go back to doing what they were doing before.

A similar situation arose following the Second World War, although it took a slightly different form with, for example, the many hundreds of women who had played such a key role in code-breaking at Bletchley Park being largely ignored in history. This led indirectly in the late 1940s and 1950s in the UK to the creation of a new grade in the civil service for programmers in the emerging computing sector who were almost entirely female, low paid and with virtually no prospect of promotion (Hicks 2017).

The principle that all careers should be equally open to men and women is clearly a fundamental prerequisite to increasing the numbers of women entering the engineering career pipeline. And in the past this has definitely been a problem. Women were not admitted to many universities in some cases until well into the 20th century. It is hard to accept, let alone explain, that the supposed bastion of liberal and enlightened thinking (universities) were so late in admitting women. For example, the Engineering School at Cambridge University was founded in 1875, yet the University did not award degrees to women – even though they could attend lectures and sit examinations – until 1947. The Engineering School in Trinity College, Dublin, was founded earlier in 1842 but women were not admitted to the University until 1904 and it was not until 1970 that the first woman graduated in Engineering. The first woman in Europe to graduate with a degree in engineering in Europe is thought to be Alice Perry in 1908 from Queen's College, Galway (now the National University of Ireland, Galway).[6] Are we not surprised to learn that the École Polytechnique in Paris first admitted women in 1972!

However, while women may have been eligible to study engineering for many decades, many were undoubtedly actively discouraged by their teachers, and parents. Engineering was simply not regarded as a career suitable for a young woman. Nursing and teaching were seen as much more appropriate. Indeed in Ireland, for example, up until 20 or so years ago, a number of all-girls schools did not offer

[6] https://en.wikipedia.org/wiki/Alice_Perry

Mathematics, Physics or Chemistry at a sufficiently high level to allow pupils to qualify for entry to degree-level programs in Engineering (Department of Education 2001). A few made arrangements for determined girls to study the subjects at the local boys school. Fortunately, that is now no longer case and all the pre-requisites for studying Engineering are almost universally available.

This chapter is not concerned with analyzing the reasons why fewer girls than boys choose to pursue careers in engineering. In summary, there would appear to be a lack of understanding among the general public, including many teachers, school pupils, and their parents, about what modern engineering practice entails. There remains the image of the oily overalls and the hard hat! There are many excellent initiatives and resources to counteract these images (e.g. the excellent video by the American Society of Civil Engineers[7]). Therefore it is reasonable to assert that in principle engineering is a career which is equally open to both women and men, even if fewer women than men choose to avail of the opportunity. However, it must also be acknowledged that there is evidence to suggest that while girls outperform boys at high school virtually everywhere, those who have performed well in Mathematics, a pre-requisite for most engineering degree programs, are proportionately less likely than boys to pursue careers in mathematically-oriented degree courses, such as engineering.

15.3.2 Talent

The second argument for eliminating gender inequality relates to the loss of talent which is clearly evident from the failure to attract and retain women in the engineering profession. This would not be a problem if there was not a general shortage of engineers. In Europe, science and engineering professions are amongst the top three shortage groups. Engineers are at the heart of solving the major challenges worldwide including climate change, population growth and food security, ageing, and global health. The question is: where can we find the talent that is so urgently required? As CP Snow said in his famous book *The Two Cultures*:

> It is one of our major follies that, whatever we may say, we don't really regard women as suitable for scientific careers. We thus neatly divide our pool of potential talent by two.

To address the shortage we must therefore increase the participation of talented women (and indeed other under-represented minorities, but these are not the subject of this chapter) in engineering. The relatively low numbers of women pursuing engineering qualifications represents a significant loss of *potential* talent to the profession but the failure to retain and promote them within the profession represents a loss of *actual* talent.

[7] https://www.youtube.com/watch?v=iI8ZoFgrrHY

15.3.3 Diversity

The third, and perhaps the clinching argument, in favor of greater gender equality in engineering is the need for greater diversity. It is the need for greater diversity which is at the heart of the business case for addressing gender inequality in the corporate world. We have already noted that the culture within engineering is largely homogeneous and male but there is now incontrovertible evidence that diversity contributes to innovation, creativity, better-decision-making and ultimately increased profits. But we should not have to argue the point today on the benefits of gender diversity and to have to look for data to prove the value of women in the workforce for the evidence is utterly compelling: in times of great need women demonstrated that they had the ability to undertake what some would have previously defined as men's work (for example in war when men were otherwise occupied).

In other domains, when the opportunity arose women were not found lacking in ability, application, ingenuity and flair. From conducting orchestras to leading in science women have demonstrated time and time again their capabilities to be of the first rank.[8] There is also the question of the benefits of women and men working together. Relatively recently, a survey by Gallup (Badal 2014) found that "gender-diverse business units have better financial outcomes than those dominated by one gender" and specifically that:

- Gender-diverse business units in the retail company have 14% higher average comparable revenue than less-diverse business units (5.24% vs. 4.58%).
- Gender-diverse business units in the hospitality company show 19% higher average quarterly net profit ($16,296 vs. $13,702) than less-diverse business units.

At its heart, engineering is about solving problems whose solutions matter to people – both women and men. It is about finding solutions to often highly complex problems to which numerous constraints may apply. These may be financial, environmental, safety, etc. It is therefore a highly creative and collaborative endeavor which is largely carried out in teams. Research has clearly demonstrated that diverse teams are more creative; the different perspectives, experience and knowledge of the different members of the team provide different ways of looking at the problem and therefore potentially also different solutions (London Business School 2007). At a management level, diversity avoids the pitfalls of group-think (McKinsey and Company 2010; Noland et al. 2016).

As a general rule, women and men bring different and above all complementary approaches to problem-solving and decision-making, although this can work to the disadvantage of women. Men and women have different leadership styles with women putting more emphasis on collaboration than men. This can have the effect of making women seem to be indecisive or deferential and unwilling to assert their own point of view (Flynn et al. 2011; McKinsey and Company 2013). In turn this can be interpreted as women appearing to be less ambitious, when judged against a

[8] And often against prevailing prejudices (e.g. Émilie du Châtelet and Marie Curie).

male corporate culture (Rice 2012). And as we saw earlier, the male culture prevalent in engineering enterprises is one of the key reasons why women leave the profession in greater numbers compared to their male colleagues.

Early in 2016, the US Office of Science and Technology Policy (OSTP) called for the scientific community to review the evidence in relation to diversity. Smith-Doerr et al. (2017), responding to the call by the OSTP, conducted a comprehensive review of the literature and not surprisingly found it was fraught with contradictions. “Some studies find that diverse teams outperform more homogenous teams while others do not”. One aspect that emerged in the literature was the differentiation between simply having the presence of women and other minorities in an organization or team and their full integration. Diversity by itself does not guarantee beneficial outcomes. To realize the hoped for benefits “minority workers must be integrated – both in sufficient numbers and in organizational spaces that involve non-hierarchical interactions on teams – in order for racial and gender diversity to yield benefits”. Evidence was found that the collective ability of a group exceeded the sum of the individual abilities. Of particular relevance to engineering, diverse teams, it was found, can generate a broader range of solutions to whatever problem is being considered. Two explanations are, first, that diversity brings with it intellectual diversity (different thinking). Second, diversity has the advantage that it brings with it a wider social network and hence the capability of tapping into a wider base of experience and knowledge. Another aspect that is stressed is the need to avoid “tokenism”. Not only must there be a minimum minority representation (figures range from 15% to 30%), there also needs to be a conducive atmosphere, including informal relationship between team members of respect and trust if there is to be a positive outcome.

Finally, from a purely commercial perspective, 50% of the population is female and therefore so are the end-users/customers of engineering artefacts. Ignoring their perspectives and input is to say the least fool-hardy and may indeed be dangerous. One of the most frequently-cited examples from the engineering domain relates to the use of crash-test dummies in the design of seat-belts in cars[9]. Men were used as the norm in the design of the initial crash test dummies for cars in 1949. A model female dummy was introduced in 1966 and children were added in the 1980s. However, it was not until 1996 that the first pregnant crash test dummy was designed and up until at least 2012 they were still not used in government-mandated auto safety testing in the U.S. or by the European New Car Assessment Program. Conventional seatbelts do not fit pregnant women properly, and motor vehicle crashes are the leading cause of fetal death related to maternal trauma. The use of seatbelts during pregnancy remains a major safety concern.

[9] https://genderedinnovations.stanford.edu/case-studies/crash.html

15.4 Tackling Gender Inequality

The starting point for addressing gender equality is to gather and analyze data – both quantitative and qualitative. This analysis should help to identify what the particular challenges women within an organization face and therefore point to where action should be taken. This should lead to a comprehensive Gender Action Plan (GAP) or equivalent[10] with clear and measurable targets. Progress should be measured and publicly reported. An analysis of a number of GAPs and Diversity Strategies reveal, not surprisingly, a number of common themes. We will consider four in particular, namely:

- Leadership
- Work-life balance
- Women leaders
- Unconscious bias

15.4.1 Leadership

The elimination of gender inequality must be a key strategic objective of the organization led from the top – the President/Vice Chancellor of the University or the Chief Executive of a company. There must be clear lines of responsibility and accountability. In the context of academia, for example, it is common practice to establish an Equality or Diversity committee with broad representation from across the University community and this is undoubtedly important. But a committee cannot be accountable for implementation. If gender equality is to be mainstreamed within an organization – academic or corporate – then managers at all levels must be accountable for progress. It must be a core value of the organization and be part of its culture. Changing the culture of any organization is a complex and challenging task. The cultural elements of an organization comprise an interlocking set of goals, roles, processes, values, communication practices, attitudes and assumptions that mutually reinforce each other and combine to resist change (Denning 2011). Determined, committed and sustained leadership over a number of years is required and a willingness among the whole community to challenge cultural norms and the status quo.

15.4.2 Work-Life Balance

There can be no doubt that there is increasing pressure on employees across all sectors as a result of continuous performance review and increased expectations whether it is to publish more papers in academia, or working to very tight deadlines

[10] It might take the form of a Corporate Gender Equality or Diversity Strategy.

in industry. This is challenging and potentially stressful for everyone. But one cohort who are particularly adversely affected are those – usually women – returning to work after an extended period of leave (e.g. maternity or careers leave) who are trying to balance the demands of the workplace with the demands of caring responsibilities. Balancing the increasing demands of a pressurized working environment with the demands of caring for a young family is difficult. With the result that all the evidence shows that many women either decide to "go slow" in their career or indeed to leave altogether. In academia, women returning from maternity leave may opt to concentrate on teaching and administrative duties at the expense of their research with a consequential negative impact on their promotional prospects (Mason et al. 2013). In industry, they may decide not to put themselves forward for promotion preferring to "mark time". However, "marking time" in the fast moving world is likely to be detrimental to future career prospects. In order to account for interruptions in careers due to caring responsibilities, the traditional approach has been to simply "stop the clock" i.e. to give women longer to reach the notional "standard" required (e.g. to achieve tenure). But that is no longer regarded as fair or equitable. Indeed a Dutch study showed that women lost out when applying for full professorships as a result of being older (Van den Brink 2010, p. 145).

Research shows that women faced with returning to work after maternity leave, which may last for a year or more, can find it difficult to catch up. This of course raises the question as to why we expect them to "catch up". It is generally recognized that there needs to be greater emphasis on the *quality* and *impact* of outputs rather than simply of *quantity* (Sahel 2011 and Grimson 2014). This issue is discussed further under the section on Unconscious Bias below. A key facilitator of enabling employees to achieve a better work-life balance generally but especially during the relatively short period of time when they are trying to juggle the demands of caring for a young family with the demands of work is the availability of flexible working arrangements. These can take many different forms including, for example, part-time working, job-sharing, reduced working year (useful to allow parents to take extra unpaid leave during school holidays), remote working and flexi-time. All the evidence shows that women are far more likely to avail of such arrangements. A comprehensive study across the EU countries of flexible working and its association with gender equality concluded that to have a positive effect on gender equality:

> ... flexible working time schemes should be carefully designed, so that the preferences of the employees are taken into account. In addition, the organizational culture plays an important role. As long as flexibility is still considered a 'female' way of organizing working time, flexible working time schedules are more likely to confirm gender differences than to change them.

15.4.3 Women Leaders

There is little evidence to support the notion that women do not want to reach the top. Indeed the McKinsey 2013 *Women Matter* Report concluded that women are as ambitious as men to reach the top within their organizations. However it also showed that women were significantly less confident than men that they would actually succeed in achieving senior positions. It is particularly important to note that confidence was defined "as a perception of one's chances of success in the current environment, rather than confidence in one's own qualifications".

There are numerous initiatives in different sectors which seek to identify at a relatively early stage young women of high potential and support them through leadership and development programs to become future leaders (see Case Studies below). It is a widely acknowledged phenomenon that when applying for a position or for promotion, women tend to look at all the criteria and unless they meet all of them they will not apply. In general, they are more risk-adverse than men. These leadership programs not only aim to boost the confidence of women in their own abilities but also to understand the pros and cons of different leadership styles – and above all to value their own style. It is not surprising that there are mixed views about such programs among both women and men. On the negative side, they can be criticized for giving women an unfair advantage with respect to promotion over their male colleagues. The sub-text here is that such programs will lead to less deserving women being promoted over more deserving men. Furthermore, by being exclusive to one group, they are also seen as running contrary to the principles of diversity and inclusion. On the positive side, however, the experience of women participating in these programs is overwhelmingly positive. In most cases it is too early to say whether they will lead to a significant increase in women leaders (Barnard et al. 2016).

15.4.4 Manage Unconscious Bias

It is clear from extensive research in a number of countries and within different organizations and in different sectors that unconscious bias is widespread among both women and men and its effect is to advantage men over women (Moss-Racusin et al. 2012). Merton (1968) also showed that established researchers are consistently given more credit than is merited (the so-called "Matthew effect"[11]). The participation of women in engineering varies considerably across the different engineering disciplines but the only sector where the participation has been dropping over the past three decades is software engineering and ICT generally. It is therefore encouraging that companies such as Intel,[12] Google, Yahoo, LinkedIn and Facebook (Williams 2015) have recognized that they have a problem with the lack of women within their organizations and in particular the lack of women in senior leadership positions and decided to tackle the issue. As Williams put it "It is remarkable that the sector is finally stepping up to the plate on diversity – and refreshing that its

[11] To those who have more shall be given. In the King James Bible, Matthew 25:29; "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath".

[12] https://www.intel.ie/content/www/ie/en/diversity/diversity-at-intel.html

focus is on metrics rather than rhetoric". A major element of these companies' diversity strategies – and indeed the equivalent strategies in universities – is tackling unconscious bias.

Examples of the impact of unconscious bias can be found across multiple sectors. In the US in the 1970s, only 5% of the members of the top 5 orchestras were female (Goldin and Rouse 1997). It was decided to introduce blind auditions whereby in the initial round(s), applicants were seated behind a partition and could therefore only be heard and not seen. This resulted in the probability of a woman being hired jumping from 25% to 46%. Similar results were found in academia. In a randomized double-blind study by Moss-Racusin and colleagues (Moss-Racusin et al. 2012), 127 science faculty from a number of different universities were asked to rate the (fictitious) application materials of a student – who was randomly assigned either a male or female name – for a laboratory manager position. All participants, both male and female, rated the male applicant as significantly more competent and hireable than the (identical) female applicant. This and other similar evidence has led to many research funding bodies and journals today to introduce blind reviewing where the identity – and gender – of the applicants/authors is unknown to the reviewers. While removing identifying details works well in situations where there are large numbers of applicants and therefore it is unlikely that it will be possible for reviewers to identify individuals, it is not possible in interview situations or in applications for promotions within organizations. In these situations, it is important therefore that all those involved in the recruitment/promotion processes undertake comprehensive unconscious bias training. Clearly such training cannot eliminate unconscious bias because, as the name implies, it is simply that 'unconscious'. However, it is possible through training to help us all to recognize our own biases and to make sure that they do not adversely affect the objectivity of our judgements.

Unconscious bias is at the heart of what is referred to as the "meritocracy paradox". Meritocracy is a value which is cherished by many organizations, including, in particular universities, and is encapsulated in statements such as "We recruit and promote purely on merit". Yet, paradoxically, Castilla and Benard (2010) found that "when an organizational culture promotes meritocracy (compared with when it does not), managers in that organization may ironically show greater bias in favor of men over equally performing women in translating employee performance evaluations into rewards and other key career outcomes". The "paradox of meritocracy" therefore supports the view that there are many, often unconscious, biases within organizations which combine and interact to advantage men and disadvantage women.

This brings us to the question of how merit, success and excellence are judged within an organization. What constitutes academic excellence (e.g. journal rankings, citation indices, peer review systems, membership of editorial boards, and level of networking) is highly gendered and disadvantages women (for example, see van den Brink and Benschop 2011; Rees 2011; Husu and Koskinen 2010). The loss of women's talent has major implications for research quality (Grimson 2014). It is virtually impossible to eliminate gender inequality and ensure that women can reach the top leadership positions within universities or indeed in the corporate world if the criteria being used to assess merit are not gender neutral. For example, the career trajectories of men and women are often different, with women being much more likely to take periods of leave. They can therefore be at a disadvantage if – even unconsciously – the *quantity* of achievements (e.g. publications in the case of an academic, or projects managed in the case of the engineer) influences the assessment of their merit.

15.5 Two Case Studies

Two examples are presented in which gender inequality is addressed in very different domains and for very different reasons. However, as will be seen, the underlying issues of recruitment, retention and promotion are perhaps not surprisingly in evidence and the solutions put in place are not dissimilar.

15.5.1 National University of Ireland Galway Case Study

Even in a climate where there is genuine acceptance that equality issues need to be addressed, progress can be so slow and it can take a major external intervention or event for action to be taken. In the case of National University of Ireland Galway (NUIG), decisive action to address gender inequality was triggered when the University lost a major equality case. A member of the academic staff at the University, who was unsuccessful in an application for promotion, claimed that she had been discriminated against on the grounds of gender. She took a case to the Equality Tribunal and the Tribunal found in her favor.[13] The case attracted significant adverse publicity and reputational damage for the University with the result that the Governing Authority (Údarás na hOllscoile) of University in February 2015 decided to establish an independent task force with the remit:

> To consider the University's present gender mix among staff, including academic and support staff, and advise the University what measures it should take to develop effective gender equality.

Whilst technically the Task Force could only 'advise' the Authority there was an expectation in most quarters that if its recommendations were well founded and evidence-based they would be taken seriously and in practice hard to reject. Put another way, the work of the Task Force was not to be an exercise in "kicking the can down the road". It is fair to note that the whole higher education sector in Ireland watched with interest how matters would progress. What follows is a short account of its salient features including a summary of its key recommendations. First though it is worth noting that the Chair of the Authority, a former Supreme

[13] http://www.adarehrm.ie/news/hr-employment-law-news/2015/01/12/the-equality-tribunal-published-9-decisions-for-november-2014

Court Judge, stressed in the Report's Foreword that 'its evidence-based approach' and hence the recommendations 'gain particular strength from the evidence which it has assembled and analyzed'.[14]

The approach adopted by the Task Force was to gather evidence on which to base its recommendations from within the University, from national and international documents, reports and peer-reviewed research on gender equality generally and in academia in particular, as well as briefings on specific topics relevant to their work. Of particular relevance was information about and experience of the Athena SWAN awards systems originally based in the UK but extended to cover Irish higher education institutions in 2015.[15] There are three grades of award – bronze, silver and gold – and they can be awarded at Department/School level and at institutional level. Initially focused exclusively on Science, Technology, Engineering, Mathematics and Medicine (STEMM), the awards were aimed at improving both the recruitment and retention of women in STEMM subjects in UK universities. The process of applying for an award involves gathering and analyzing comprehensive gender-disaggregated data, both qualitative and quantitative, within the school/department/institution, identifying where the challenges for women are and developing a Gender Action Plan to address these. To date, only eight schools (and no institution) have received a gold award – and as yet no engineering school/department, although there are a few with silver awards.

At a very early stage, it was clear that major cultural change was required in order to eliminate gender inequality at NUIG. Bearing that in mind, the Task Force operated insofar as was possible in an open and transparent manner, making the minutes of its meetings available on the web, and consulting widely with and receiving submissions from the University community. Two major consultations were held, one early in the process and the second near the end. The first consultation invited members of the University to submit their views confidentially to the Task Force chair on the University's approach to gender equality and to identify instances where they felt there was evidence of gender inequality. The second consultation was based on the Draft Final Report and respondents were invited to comment on the report and make suggestions for changes. The Task Force received many excellent suggestions and carefully thought out proposals and there can be no doubt that the end-product was improved as a result.

15.5.2 Task Force Recommendations

The task force made a total of 24 recommendations grouped under the headings: Leadership and governance; Policies and procedures; Capacity building and training; and Monitoring and implementation. Without commenting on all 24

[14] The final Report of the Gender Equality Task Force, NUI Galway is available at https://www.nuigalway.ie/media/nuigalwayie/content/files/aboutus/Final-Report-Gender-Equality-Task-Force-260516.pdf

[15] http://www.ecu.ac.uk/equality-charters/athena-swan/

recommendations a few deserve special mention. The first and arguably the most important recommendation was that the University should create a new post, namely that of a Vice President for Equality and Diversity (VPED) who would have overall responsibility and accountability for gender equality (and subsequently for diversity more generally) in the University. Implementation of this recommendation required significant financial investment at a time of reducing budgets to higher education in Ireland.

The 'Monitoring and implementation' recommendations address what has always been a weak area of positive intervention. To that end and to maintain focus, the VPED is charged with making annual reports to the Governing Authority based on comprehensive quantitative and qualitative data. In addition, the VPED is required to develop a Gender Action Plan based on the 24 recommendations and consistent with the university's application for the Athena SWAN Bronze award. The day-to-day actions are the responsibility of a high level university officer but correctly overall responsibility lies with the Governing Authority. Under 'Leadership and governance' in addition to the creation of the new post of VPED, it was recommended that committees and working groups should have a minimum of 40% women and 40% men. Further a target of 50% women in respect of the chairs of major and influential committees be women was proposed.

Under 'Policies and procedures' 11 recommendations were made covering topics such as role models, support programs, guidelines for promotion, workload and core hours, but the most significant, and to some extent the most controversial one, concerned gender quotas for academic promotion. The recommendation on quotas was based on the flexible cascade model in which the quota to be promoted is directly related to the number of women eligible for promotion at the grade immediately below the promotion level (Wallon et al. 2015). Clearly this will not instantly result in gender balance but it is held to be the fairest and best option for the medium to long term outcome, and ensures at a minimum that the pipeline does not leak.

Finally, regarding 'Capacity building and training' of the eight recommendations the main and critical one, bearing in mind that the underlying problem is in essence a cultural and behavioral one, concerns unconscious bias. The recommendation made was that all members of the university and academic management teams, heads of school, chairs of committees, members of interview and promotion boards, and other senior decision-makers attend compulsory unconscious bias training annually. At the time of writing, a mere 12 months after publication of the report, significant progress in implementing the recommendations has been made. Of course, it is too early to say whether this will in turn lead to the necessary cultural change. The actions proposed in the recommendations after all are simply proxies for changing the culture.

Shortly after the Task Force commenced its work, Ireland's Higher Education Authority (HEA) – the body responsible for funding of the sector – instigated a review of gender equality across the entire sector. Its Report was published shortly after that of the Task Force and many of the Task Force's recommendations were included in the HEA's recommendations.[16] And arising from that Report, three of the major research funders, Science Foundation Ireland, the Irish Research Council and the Health Research Board have indicated that in order to be eligible for funding, the institution of the applicant must hold at least a bronze Athena SWAN award by 2018 and a silver by 2023.

15.5.3 INTEL Case Study

In 2015 the CEO of INTEL, Brian Krzanich, set an ambitious goal to be the first high technology company to reach full representation of women and underrepresented minorities in its U.S. workforce by 2020. He committed $300M to support this goal and accelerate diversity and inclusion – not just at Intel, but across the technology industry at large. The scope of Intel's efforts spans the entire value chain, from spending with diverse suppliers and diversifying its venture portfolio so as to better serve consumer markets and communities through innovative programs like Hack Harassment, which aims to combat online harassment.

This was part of an overall mission to address diversity, including but not limited to gender, not just for ethical reasons but also because it would contribute to the overall objectives of the company and enable it to become a leader in inclusion in the field of technology.[17] The benefits of having different and richer perspectives, improved teamwork, and enhanced capacity to find novel and innovative solutions were to the fore. In summary five overall objectives were identified, as follows:

1. Achieve full workforce representation through hiring and retention by 2020,
2. Grow the pipeline of diverse and rich talent for technology industries via scholarships and activities in schools for STEM subjects,
3. Improve diversity in the vendor supply chain,
4. Invest in diverse entrepreneurs of emerging technologies,
5. Drive inclusion in a smart connected world.

It was realized that strong high level leadership would be required to translate these objectives into reality and that the transformative nature of what was required would demand accountability at board and executive level. A Vice President (Chief of Diversity and Inclusion Officer) was appointed and as an aside it is worth noting that in 2017 41% of the Vice Presidents in the company are women. However whilst the figure for the overall Global non-technical workforce is 50% only 25.8% of the staff in the technical area are women.

To give an indication of the scale of what is being attempted, and hence the challenge, the following numerical data is available from Intel (Fig. 15.2):

[16] http://hea.ie/sites/default/files/hea_review_of_gender_equality_in_irish_higher_education.pdf

[17] https://www.intel.ie/content/www/ie/en/diversity/diversity-at-intel.html

	Global (non-technical) Dec 2016	% change since Dec 2014
Female	7,635	-3.88
Male	7,610	3.85

	Global (technical) Dec 2016	% change since Dec 2014
Female	18, 524	1.46
Male	67,515	-1.49

	Global (leadership[a]) Dec 2016	% change since Dec 2014
Female	73	0.8
Male	322	-1.05

Fig. 15.2 Gender breakdown of Intel Staff, 2016 and 2014
[a]Grades 12+ in Intel's classification
https://www.intel.com/content/www/us/en/diversity/diversity-2016-annual-report.html?eu-cookie-notice

Very simply, the challenge is greatest at the leadership level whilst at the technical level the gender ratio is approximately 3:11, indicating that there is plenty of scope for improvement offering significant potential benefit to the company by addressing diversity in the workforce. Intel has had a strong presence in Ireland since 1989 employing over 4500 people at its wafer fabrication facility at Leixlip outside Dublin.[18] In Ireland a set of measures has been put in place to implement the company's policy on diversity. Considered as a pipeline, the task is to attract young women to study STEM subjects in the first place, then to hire them and ensure they are supported and encouraged to remain in the workforce in rewarding and satisfactory roles. Finally so that the pipeline does not 'leak' the challenge is to ensure a certain percentage of women are identified, mentored and promoted to the higher and highest levels in the organization. The measures have five strands:

1. Attracting students,
2. Hiring,
3. Integration and support,
4. Female leadership and progression programs,
5. Branding.

In 'Attracting female students' to study STEM subjects up to Leaving Certificate level (pre-university), a number of programs have been put in place**.** Some of which include: scholarships are offered to the top females who go on to study STEM subjects in Higher Education Institutions; partnerships with universities are used to support and encourage female studentships through work experience placements in

[18] https://www.intel.ie/content/www/ie/en/company-overview/intel-ireland-overview.htm)

Intel; and a mini-scientist program is run in-house for young children to let them see and understand what science is and to help eliminate any misunderstandings about the subject in general.

Regarding ‘Hiring’, actions include training for interviewers, utilizing balanced interviews (dealing with behavioral aspects and not just technical matters) and balanced hiring panels. In addition a return-to-work program for women is being considered.

For ‘Integration and Support’ a mentoring ‘buddy’ system is in place based on the original concept of an arrangement in which, usually, a pair of individuals work together and assume to some extent responsibility for each other’s wellbeing (not just technically but also in terms of relationships). The company in Ireland also has in place a Women in Intel network (WIN) which seeks to leverage all the positive features of belonging to a network, such as shared experiences. In addition an annual WIN conference brings together members to celebrate achievements and to provide an environment in which they can learn from each other.

If ‘Integration and Support’ is the key measure for the majority of female staff the next measure ‘Female Leadership and Progression Program’ is critical in addressing the under-representation of females at the higher levels of management, particularly on the technical side of the business. The approach adopted is one of a senior member of staff, in this case a factory manager and Vice President, who identifies and selects individual women who are at a relatively early stage in their careers but who have demonstrated excellent performance. They will be mentored through a series of stages before becoming ready and eligible for senior management and leadership roles. It is stressed that only exceptional individuals are chosen, in order to avoid the potential criticisms of women-only leadership programs referred to earlier.

Finally ‘Branding’ is important as part of spreading the message externally as to the benefits of diversity and inclusion as well as embedding diversity and inclusion internally within the company through on-site events. All of the above would merely be termed as worthy and little more than an aspiration unless it was driven by genuine intent coupled with strong leadership. The evident commitment from the CEO coupled with on-the-ground leadership in Ireland indicates that an effective set of implementable policies are in place.

15.6 Analysis of the Two Case Studies

The motivations for addressing gender inequality in the two case studies are somewhat different but it is interesting to reflect on these differences and the similarities. In both cases, the organizations were already well aware that women were under-represented – in the case of Intel at all levels, and in the case of NUI Galway at senior levels including full professors. Intel had already begun to take action at local level; there have been programs in place in the Irish plant for many years. By contrast, NUI Galway largely took the view that promotion was based on merit and therefore by definition there could be no discrimination. In both cases, however, the drive to address the problem pro-actively came from the top, namely the Chief Executive in Intel's cases and the Governing Authority in NUI Galway's case. So what was it that prompted them to take action? And here there is a fundamental difference. In the case of Intel, the CEO was convinced by the growing body of independent evidence that diversity among the entire workforce at all levels is essential to enhancing innovation, improving decision-making and recruiting and retaining the best talent. Thus diversity was seen as vital to securing the company's future sustainability and profitability. By contrast, NUI Galway only began to address gender inequality when it lost the equality case in 2014. Thus their actions to address the issue were largely reactive as opposed to Intel's which were largely pro-active.

To facilitate the comparison between the two case studies, the five strands of Intel's diversity programs are used.

15.6.1 Attracting Students

In terms of the actual actions taken by NUI Galway and the Irish Intel facility, as an exemplar of the corporate approach, they show great similarities. The College of Engineering and Informatics in NUI Galway are very actively involved in seeking to attract more young women into their courses. And indeed the Bioengineering degree probably has the highest proportion of female students of all engineering programs in the country.

15.6.2 Hiring

Both organizations put considerable effort into seeking to recruit the best possible staff. Virtually all full professorships at NUI Galway are recruited by external competition with a search committee pro-actively seeking to attract applications from suitably qualified candidates from across the globe. By contract, most appointments to senior positions within Intel are generally filled through internal promotion. As the exceedingly low percentage of full female professors (14%), the joint lowest in the Irish higher education sector, demonstrates that there is a marked gender difference at this level and a very leaky pipeline.[19] An analysis of the application and

[19] Fifty-two percent of lecturers (entry level academic grade) are female at NUI Galway, 30% of senior lecturers, 13% of Associate Professors and 14% of Full Professors [https://www.nuigalway.ie/media/nuigalwayie/content/files/aboutus/Final-Report-Gender-Equality-Task-Force-260516.pdf].

shortlisting data would indicate that the problem is not that women are less successful than men but rather that they apply in very low numbers. This is consistent with the findings from other universities and seems to be attributable to three main factors. Firstly, the search committees and the selection committees are comprised in the main of senior academics, who inevitably are more likely to be men.

Secondly, the search committees which are charged with seeking out potential candidates tend to look within their own networks and as women are less well networked, the resulting list may therefore include more men than women – unless the search committee makes a real effort to look beyond the "usual suspects". Finally, when potential female candidates are identified and approached, it is frequently the case that they are not in a position to relocate usually because of family commitments – the so-called "two body problem of academia". A study in the US found that 89% of women academics had full-time working partners compared to only 56% of men. Women are typically less mobile in the job market generally. In order to address these problems, the NUIG Task Force made a number of recommendations including ensuring that search and selection committees were gender balanced using outside expertise where necessary and making a real effort to ensure that shortlists of candidates are gender balanced. Addressing the mobility problem is clearly difficult although many institutions are looking at ways of securing meaningful employment locally for the partner of potential appointees.

Intel already has in place unconscious bias training for those involved in hiring staff and NUI Galway is in the process of introducing such training. It is perhaps worth noting that universities traditionally have tended to resist compulsory training of academic staff in any area, but the situation is changing rapidly with increasing external scrutiny of academic procedures and processes as well as an increased willingness on the part of unsuccessful candidates to challenge decisions. This potentially works in favor of female candidates who, by and large, prefer greater transparency in recruitment procedures and processes.

15.6.3 Integration and Support

On integration and support, NUIG has had an active Women's Network in place for a number of years, the equivalent of Intel's WIN. Both organizations have – in the case of Intel – and will – in the case of NUIG – have mentoring or the equivalent systems in place. Crucially, the Task Force also recommended the introduction of quotas for promotion – specifically the flexible cascade model – in NUIG. While Intel does not operate a quota system, it is possible to draw parallels between quotas and the program operated in Intel Ireland to nurture and develop future female leaders. Both approaches, either directly in the case of Intel, or indirectly in the case of NUIG, aim to develop self-confidence among women and increase their chances of success. In NUIG, for example, women informed the Task Force that they did not think it was worth applying for promotion since the chances of success were so small.[20] This reflects the widely acknowledged phenomenon that, when applying for a position or for promotion, women tend to look at all the criteria and unless they meet all of them they will not apply. In general, they are more risk-adverse than men. It should also be noted that the Task Force report recommended increased participation in the Aurora program which aims to develop future female leaders in academia.[21]

15.6.4 Branding

The final pillar of the Intel Ireland strategy is branding, both internal and external, and both case studies demonstrate work in this area. NUI Galway is increasing the visibility of women researchers and promoting positive role models. This includes everything from pictures and portraits on walls, naming of building and lecture halls. The new engineering building at the University has been named after its first female engineering graduate, Alice Perry. In Intel Ireland, there are a selection of photographs of female technical talent in the Reception area. In both cases, International Women's Day/Week is used as an opportunity to celebrate the successes of women. It is not possible to positively assert that these case studies are typical of the two sectors – the engineering/technology sector and academia. But there can be no doubt that both organizations have expressed high ambition – in Intel's case to be the leader in diversity and inclusion in the Technology sector, and in NUI Galway's case to be a leader in gender equality in the higher education sector in Ireland.

15.7 Conclusions

Looking back over the last 100 years or so, it is, on reflection, astounding how little and late real changes were made to give women a proper place in society. One might have expected following the Enlightenment that 'progress' however defined would have accelerated. Take France for example in its post-revolutionary period. For a country so proud of its *liberté, **égalité**, fraternité,* it is somewhat surprising that Attatürk granted women the vote in Turkey several years ahead of women being granted the vote in France.[22] And we have already mentioned the late admission of

[20] This has been exacerbated in recent years by the very limited number of promotions available due to financial constraints arising from the economic crisis in Ireland in the 2008.

[21] The Aurora Program is a women-only leadership development program. It is a unique partnership initiative bringing together leadership experts and higher education institutions to take positive action to address the under-representation of women in leadership positions in the sector.

[22] Universal suffrage was introduced in Turkey in 1934. Women were first allowed to vote in France in 1945, but only if they were literate! The final restrictions on women's voting rights were not removed until 1965.

women to universities. These seemingly unconnected events are relevant as they are part of how the establishment and hence society viewed women. And whilst progress occurred at different times and at different rates across the world, there is bound to be residual echoes of past discrimination deeply embedded throughout many organizations in today's world. Academia and Engineering being just part of society cannot therefore change globally persistent inequalities that are rooted in culture. They can however recognize the symptoms in their own domains, and set in motion steps to address the causes and in turn provide leadership to a wider audience.

There is no evidence to support the contention that gender inequality will reduce over time in some form of natural or spontaneous manner. What is absolutely clear, however, is that gender equality in engineering will only be achieved as a result of sustained positive interventions. Failure to take action will have a major impact on the profession's ability to meet the needs of society today and tomorrow.

References

Badal, S.B. (2014). The business benefits of gender diversity. *Business Journal,* January 20, 2014. Available at: http://www.gallup.com/businessjournal/166220/business-benefits-gender-diversity.aspx. Accessed 26 June 2017.

Barnard, S., Arnold, J., Bosley, S., Munir, F. (2016). *Onwards and upwards? Tracking women's work experience in higher education summary* [online]. Available at: https://www.lfhe.ac.uk/en/research-resources/research-hub/2016-research/onwards-and-upwards-tracking-womens-work-experiences-in-higher-education.cfm?utm_source=research&utm_campaign=aurora. Accessed 29 June 2017.

Bothwell, E. (2015). World's top 10 universities led by women. *Times Higher Education*, June 19, 2015. [online] Available at: https://www.timeshighereducation.com/carousels/worlds-top-10-universities-led-women. Accessed 26 June 2017.

Castilla, E. J., & Benard, S. (2010). The paradox of meritocracy in organizations. *Administrative Science Quarterly, 55*, 543–576.

Denning, S. (2011). How do you change an organizational culture? *Forbes*, July 2011. [online] Available at: https://www.forbes.com/sites/stevedenning/2011/07/23/how-do-you-change-an-organizational-culture/#aa1704a39dc5. Accessed 26 June 2017.

Department of Education. (2001). *Report and recommendations of the task force on physical sciences*. [online] Available at: www.education.ie/en/Publications/Policy-Reports/Task-Force-on-the-Physical-Sciences-Report-and-Recommendation.pdf. Accessed 26 June 2017.

Engineering UK. (2016). *Engineering UK 2016, synopsis, recommendations and calls for action*. [online] Available at: http://www.engineeringuk.com/media/1309/engineeringuk-report-2016-synopsis.pdf. Accessed 26 June 2017.

European Commission. (2006) DIRECTIVE 2006/54/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 July 2006 on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation (recast). *Official Journal of the European Union,* 27.07.2006. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:204:0023:0036:en:PDF. Accessed 26 June 2017.

European Commission. (2010). *Compilation of case law on the equality of treatment between women and men and on non-discrimination in the European Union* (3rd ed.). Luxembourg: Publications Office of the EU Available at: http://ec.europa.eu/justice/gender-equality/files/case-law-compilation_en.pdf. Accessed 26 June 2017.

European Commission. (2014). *Commission staff working document. Report on progress on equality between women and men 2013*. [online] Available at: http://ec.europa.eu/justice/gender-equality/files/swd_2014_142_en.pdf. Accessed 26 June 2017.

European Commission. (2016). *SHE figures 2015 gender in research and innovation statistics and indicators*. Luxembourg: Publications Office of the European Union [online] Available at: http://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf#view=fit&pagemode=none. Accessed 26 June 2017.

Flynn, J., Heath, K., Davis Holt, M. (2011). Collaboration's hidden tax on women's careers. *Harvard Business Review*, November 11, 2011. [online] Available at https://hbr.org/2011/11/collaborations-hidden-tax-on-women. Accessed 26 June 2017.

Goldin, C. & Rouse, C. (1997) *Orchestrating impartiality: The impact of "blind" auditions on female musicians*. Working Paper 5903, National Bureau of Economic Research, Cambridge, MA. Available at: http://www.nber.org/papers/w5903.pdf. Accessed 27 June 2017.

Grimson, J. (2014). Measuring research impact: not everything that can be counted counts, and not everything that counts can be counted. In W. Blockmans & L. Engwall (Eds.), *Use and abuse in the review of research* (pp. 29–41). Denis Weaire: Portland Press Ltd..

Grimson, J., & Roughneen, C. (2009). Diversity in engineering: tinkering, tailoring, transforming. In H. Christensen, B. Delahousse, & M. Meganck (Eds.), *Engineering in context* (pp. 197–220). Denmark: Academica.

Hicks, M. (2017). *Programmed inequality. How Britain discarded women technologists and lost its edge in computing*. Cambridge: MIT Press.

Husu, L., & Koskinen, P. (2010). Gendering excellence in technological research: a comparative European perspective. *Journal of Technology Management & Innovation, 5*(1), 127–139.

London Business School. (2007) *Innovative potential: Men and women in teams*. [online] Available at: http://www.lnds.net/blog/images/2013/09/grattonreportinnovative_potential_nov_2007.pdf. Accessed 26 June 2017.

Mason, M. A., Wolfinger, N. H., & Goulden, M. (2013). *Do babies matter? Gender and family in the ivory tower*. New Brunswick: Rutgers University Press.

McKinsey & Company. 2010). *Women matter 3: Women leaders, a competitive edge in and after the crisis*. [online] Available at: https://www.mckinsey.de/files/women_matter_3_brochure.pdf. Accessed 20 March 2016.

McKinsey & Company. (2013). *Women Matter: Gender diversity in top management: Moving corporate culture, moving boundaries*. [online] Available at: http://www.mckinsey.com/global-locations/europe-and-middleeast/france/en/latest-thinking/women-matter-2013. Accessed 20 March 2016.

Merton, R. K. (1968). The Matthew effect in science. *Science, 159*(3810), 56–63.

MIT, Massachusetts Institute of Technology. (1999). *A study on the status of women faculty in Science at MIT*. [online] Available at: http://web.mit.edu/fnl/women/women.pdf. Accessed 26 June 2017.

Moss-Racusin, C. A., et al. (2012). Science faculty's subtle gender biases favour male students. *Proceedings of the National Academy of Sciences, 109*(4), 16474–16479.

National Academy of Engineering. (2008). *Changing the conversation: messages for improving public understanding of engineering*. Washington, DC: The National Academies Press 2008.

Noland, M., Moran, T., Kotschwar, B. (2016). *Is gender diversity profitable? Evidence from a global survey*. Peterson Institute for International Economics. [online] Available at: http://www.iie.com/publications/wp/wp16-3.pdf. Accessed 10 March 2016.

O'Connor, P. (2014). *Management and gender in higher education*. Manchester: Manchester University Press.

Perrons, D. (2015) Gender equality in times of inequality, crisis and austerity: Towards gender-sensitive macroeconomic policies. In *Visions for gender equality.* Luxembourg: Publications Office of the European Union. Available at: http://ec.europa.eu/justice/genderequality/files/documents/vision_report_final_en.pdf. Accessed 26 June 2017.

Portia. (2015). Report from the 2015 European Gender Summit to the European Commission and European Parliament. Mastering gender in research performance, context and outcomes. *International Women Online Journal of Distance Education,* 5 (1). [online] Available at: http://www.wojde.org/FileUpload/bs295854/File/07r_51.pdf. Accessed 26 June 2017.

Rees, T. (2011). The gendered construction of scientific excellence. *Interdisciplinary Science Reviews, 36*(2), 133–145.

Rice, C. (2012). *6 steps to gender equality*. [online] Available athttp://curt-rice.com/wp-content/uploads/2012/11/6-Steps-to-Gender-Equality1.pdf. Accessed June 26 2017.

Royal Society of Edinburgh. (2012). *Tapping all our talents* [online] Available at: https://www.rse.org.uk/cms/files/advice-papers/inquiry/women_in_stem/tapping_talents.pdf. Accessed 26 June 2017.

Sahel, J.-A. (2011). Quality versus quantity: assessing individual research performance. *Science Translational Medicine, 3*(84), 84cm13.

Scaife, W. G. S. (2000). *From galaxies to turbines: Science, technology and the parsons family*. Abingdon: Taylor and Francis (1999).

Sibley, S.S. (2016). Why do so many women who study engineering leave the field? *Harvard Business Review, August 23, 2016.* Available at: https://hbr.org/2016/08/why-do-so-many-women-who-study-engineering-leave-the-field. Accessed 26 June 2017.

Smith-Doerr, L., Algeria, S., & Sacco, T. (2017). How diversity matters in the US Science and Engineering Workforce. A critical review considering integration in teams, fields and organizational context. *Engaging Science, Technology and Society, 3*, 139–153.

Valian, V. (1999). *Why so slow? The advancement of women*. Cambridge, MA: MIT Press.

Van den Brink, M. (2010). *Behind the scenes of science: Gender practice in recruitment and selection of professors in the Netherlands*. Amsterdam: Pallas.

Van den Brink, M., & Benschop, Y. (2011). Gender practices in the construction of academic excellence: Sheep with five legs. *Organization, 19*(4), 506–524.

VDI. (2010). *European engineering report,* Verein Deutscher Ingenieure e.V [online] Available at: https://www.vdi.de/uploads/media/201004_IW_European_Engineering_Report_02.pdf. Accessed 26 June 2017.

Wallon, G., Bendiscioli, S., Garfinkel, M. S.(2015). Exploring quotas in academia, A joint study by EMBO and the Robert Bosch Stiftung. [online] Available at http://www.embo.org/documents/science_policy/exploring_quotas.pdf. Accessed 28 June 2017.

Williams, J.C. (2015) Hacking tech's diversity problem. *Harvard Business Review*, Joan Williams, October 2015. Available at: https://hbr.org/2014/10/hacking-techs-diversity-problem. Accessed June 28, 2017.

Jane Grimson Bachelors degree in computer engineering the University of Dublin, Trinity College, and Masters and Doctorate in Computer Science from the Universities of Toronto and Edinburgh, respectively. She holds Personal Chair in Health Informatics. Past President of the Irish Academy of Engineering and of the Institution of Engineers of Ireland. Fellow of the Royal Academy of Engineering and Chartered Engineer. Has published in the areas of health informatics, engineering education, and women in engineering and science.

William Grimson BAI, BA, MASc, Chartered Engineer. An Electronic Engineering graduate of Trinity College, Dublin and the University of Toronto. He has recently retired but is still actively involved in re-thinking engineering education and the relevance of philosophy to engineering and engineering education. He first worked as a R&D engineer for Ferranti Ltd before joining the academic staff of the Dublin Institute of Technology (DIT) where he was at one time Head of the Department of Electrical Engineering. He ended his career as Registrar with overall responsibility for academic quality enhancement. His academic output was and remains eclectic ranging from publications in areas as diverse as plasma physics, clinical information systems, philosophy of engineering, and development issues. He is currently a member of the Executive of the Institution of Engineers of Ireland. Past President of the Institution of Engineers of Ireland.

Chapter 16
Learning to Practice Engineering in Business: The Experiences of Newly Hired Engineers Beginning New Jobs

Russell Korte

Abstract This chapter reports on a study of the experiences of engineers beginning new jobs in a business organization. The overriding question guiding the study was: *What and how do newly hired engineers learn to work in a business organization?* Two major concepts frame this study: First is the idea of an occupational community as a setting for practice, and second, the process of socialization whereby new members of an occupational community learn how to practice.

Keywords Socialization · Occupational communities · Work groups · New hires · Engineering practices

16.1 Introduction

Interviewer: What recommendations would you [suggest] to improve the schooling for engineering?

Newly hired engineer: Schooling for engineering? I would say having more business experience.

The experiences of newly hired engineers beginning new jobs provide important insights into the complex transition that graduates undertake moving from university students to working engineers. This transition also illuminates the differences they encounter between engineering as learned in school and as practiced in a business organization. It is during this transition that graduates of engineering confront the realities of practice in a business environment that is oftentimes significantly different from the one in which they were educated. During this transition the differences between what they learned about engineering in school and what they confront in business are most salient.

R. Korte (✉)
The George Washington University, Ashburn, VA, USA

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_16

This chapter explores the relationship between engineering and business from the experiences of newly hired engineers beginning new jobs in a business organization – a global manufacturer of automobiles in the United States. These newcomers provide a unique perspective of the relationships between engineering and business practices based on their situation in the transition from school to work. The analyses of these data draw a complex picture of what it is like to begin practicing a career in engineering.

The perspective guiding this chapter is that organizations are primarily social systems in which the interactions and interdependencies among people are governed by different arrangements of complex social, technical, political, and cultural systems. As newcomers to engineering practice, they are socializing into an occupational community or community of practice within a larger organizational environment (Anderson et al. 2010; Brown and Duguid 2001; Van Maanen and Barley 1984; Wenger 2000).

Key concepts and definitions used in this chapter follow. Note that these are dictionary definitions useful as heuristics even though they are contested among the members of various occupational practices and scholarly disciplines – especially the definition of engineering (Merriam-Webster's online dictionary n.d.).

- *Engineering* is commonly considered a technical practice for the design and creation of scientifically based products or services.
- *Business* is defined as a commercial or mercantile practice primarily focused on the production and sale of products or services for economic transactions in markets.
- An *organization* or *enterprise* is an administrative and multi-functional structure designed for a particular goal or goals.
- A *commercially oriented organization or enterprise* is engaged in commerce, that is the buying and selling of goods or services.
- *Industry* is defined as a group of production or profit-making (i.e., business) enterprises.
- *Practice* is the activity of being engaged in an occupation.

The characteristics of engineering practice in business organizations vary widely (Barley 2005) depending on related markets, functions, occupations, composition of the workforce, and technologies in use. Organizations, as groups of people performing different functions, have an inherently socio-cultural interactional structure. Nested within this organizational system different functional groups (e.g., engineering, marketing, management, finance, production, distribution, etc.) go about their work both as parts of the organization and as members of an occupational community (see Fig. 16.1).

In this chapter, the idea of examining the relationship between engineering and business follows the logic that both are types of occupational communities embedded in an organizational context, designed for commercial purposes, in which different functional groups come together to form a business enterprise while they perform their work with various levels of coordination, collaboration, and conflict. These functional groups more or less follow the values, norms, identities, and

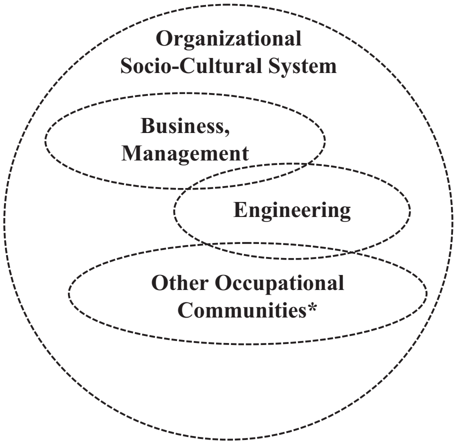

Fig. 16.1 Occupational Communities embedded in an Organizational Socio-cultural System (* Other occupational communities include manufacturing, logistics, legal, education, medical, and other professional or occupational functions)

perspectives of more specific occupational communities that govern how they work and interact with other groups (Van Maanen and Barley 1984; Wenger 2000). For example, the occupational community of business typically includes people trained in business practices for commercial purposes. The occupational community of engineering typically includes people trained in the technical work of problem solving and innovation. Even though these two communities have different educations and perspectives, boundaries can be more or less permeable as they work together in the larger business environment. The occupational communities of interest in this chapter are engineering and business management, and although these labels are widely used as separate fields they become less distinct when examined in actual practice.

This chapter reports on a study of the experiences of engineers beginning new jobs in a business organization. The overriding question guiding the study was: *What and how do newly hired engineers learn to work in a business organization?* Two major concepts frame this study: First is the idea of an occupational community as a setting for practice, and second, the process of socialization whereby new members of an occupational community learn how to practice. Both are briefly described below.

16.1.1 Occupational Communities

Van Maanen and Barley (1984) argued that organizations are comprised of more or less cohesive collections of occupational communities having a wide range of variability and idiosyncrasy. They defined an occupational community as “a group of people who consider themselves to be engaged in the same sort of work; whose identity is drawn from the work; who share with one another a set of values, norms, and perspectives that apply to but extend beyond work related matters; and whose social relationships meld work and leisure" (p. 287). The notion of a collection of occupational communities forming an organization helps illuminate the experiences of people at work more realistically than would be explained by examining a formal organizational chart and corresponding set of functional job descriptions. The organizations within which people work are more or less loosely coupled collections or congeries of occupational communities working toward a goal or multiple goals (Weick 1995). The idea of a monolithic organization with tightly coupled functional groups is more fantasy than reality.

Similar perspectives have come from those using the idea of communities of practice (Brown and Duguid 2001; Wenger 2000) and from the more recent work of practice theorists (Nicolini 2013; Schatzki 2001). Briefly, the common theme across these perspectives is that occupations, professions, and organizational work are largely social processes, highly varied, invoking the interplays of culture, identity, rules, values, power, and interpersonal relationships, as well as tools, materials, processes, and structures.

Organizational work is built around the socio-cultural dynamics of occupational communities that govern how the various groups function, how teams interact, managers manage, projects unfold, and how problems are resolved (Barley 2005). Wenger (2000) described the social fabric of an organization as an important part of a community of practice. Members of various communities could be resources to each other, exchanging information, sharing insights and new ideas, helping each other make sense of situations, and keeping each other company, as well as competing for resources, status, and power. According to Wenger, three dimensions of a community of practice are the mutuality of engagement (the ability to develop relationships that define an identity of participation); accountability to the enterprise (the ability to take responsibility for and contribute to the activities of a community); and negotiability of the repertoire (the ability to credibly and legitimately create new meaning from the historical nature of the practice). A community of practice is a locally negotiated manifestation of an occupational community of practice.

16.1.2 Socialization of New Engineers into the Workplace

Socialization is a process by which newcomers transition from outsiders to insiders by learning the tasks of their jobs, the mission of the organization, as well as the social dynamics of their workplace (Lave and Wenger 1991; Van Maanen and Schein 1979). The successful transition of engineering graduates into the workplace requires that they master the tasks of their jobs, clearly understand their roles in the organization, integrate into their workgroups, and come to understand the socio-cultural system of the organization. This transition is all the more pronounced for those recent graduates coming out of academic engineering studies and beginning engineering work in a business organization.

Some of the previous research on socialization in organizations alluded to the importance of the social domain in the integration of newcomers to the workplace (Chao et al. 1994; Cooper-Thomas and Anderson 2006; Jones 1983; Kammeyer-Mueller and Wanberg 2003; Korte 2009; Louis 1980). The idea that social processes are an important aspect of engineering practice is not new. Previous studies of practicing engineers noted the importance of social processes in engineering work (Bucciarelli 2003; Korte 2009; Trevelyan 2010; Vinck 2003). However, it seems that generally the importance of social processes in engineering practice has been underestimated – especially within the academic preparation of engineering students. One of the recurring themes in engineering education is the little amount of attention given to developing the "professional skills" that are important to engineering practice (Radcliffe 2006; Sheppard et al. 2009). Reports from employers consistently point out that engineering graduates are less prepared for organizational teamwork, communication, and project management than they are for technical work (Hanneman and Gardner 2010; Lattuca et al. 2006; Passow 2012).

In the development of this study the researcher and others proposed that some of the difficulty faced by new engineers in the workplace came from the overly theoretical and science-oriented nature of their engineering education and the differences between the technical skills and practices taught in school and the technical skills and practices needed in the workplace. Based on an initial pilot study of new engineers at work, this idea was dismissed. The pilot interviews indicated that while the technical skills taught in school were not exactly like those used in practice, or simply not used in practice, this was not much of a problem and the new engineers interviewed quickly adapted. What was problematic for these new engineers was the unexpected dominance of the social and political nature of their work. When asked what one wished he had learned in school, a new engineer sighed and said, "I wish they had taught us how to play the political game here" (Korte 2009). This sentiment recurred throughout the pilot interviews indicating that the socio-cultural aspects of organizational work were more troublesome for new engineers than the technical aspects of engineering practice. Many indicated they were blind-sided by the social, political, and cultural systems in the workplace.

The following sections recount the experiences of newly hired engineers as they learned about and integrated into their new jobs. In addition to inquiring about the technical nature of engineering practice the researcher also inquired into the socio-cultural nature of engineering practice. In-depth analyses of these data often found it difficult to separate the social from the technical as they were intricately entangled. Before presenting the findings of the study what follows is a brief description of the research design.

16.2 Research Design

Because the overall purpose of this study was to investigate complex social processes experienced by newcomers in real-life settings, I chose a qualitative, inductive case study method grounded in a naturalistic paradigm (Lincoln and Guba

1985). A qualitative, naturalistic methodology is more likely to produce new insights into complex social phenomena in the field (Eisenhardt 1989; Eisenhardt and Graebner 2007; Glaser and Strauss 1967). Additionally, case study methods are recommended when research focuses on contemporary phenomena within particular real-life contexts over which researchers have little control (Stake 1995; Yin 2003). For these reasons, a qualitative, inductive, case-study design seemed most appropriate to investigate in-depth the complex, interdependent experiences of newly hired engineers in a business organization.

16.2.1 Research Questions

The practical purpose guiding this study was to understand better the perceptions and experiences of new engineers beginning work in a business organization. The goal was to uncover opportunities for improving the socialization experiences and outcomes of new engineering graduates in the workplace. Previous research on socialization found that the experiences of newcomers often fall short of expectations and have profound effects on newcomer learning and performance (Korte et al. 2015). The guiding questions for this study were:

- What are the experiences of new engineers socializing into a business organization?
- What do newly hired engineers learn about working in their new jobs?
- How do they learn to do what they do in the organization?
- How do they view their work in the context of the larger business organization?
- What might be done to improve the socialization experiences for new engineers in the workplace?

16.2.2 Participants

The participants were recently hired by a large, U.S. based manufacturing company. The organization employed a large engineering workforce with a large number of new hires at the time of this study. Based on the logic of purposeful sampling (Patton 2002; Strauss and Corbin 1998), specifically with the goal of collecting rich in-depth information from participants, the researcher asked Human Resources (HR) managers in the company to identify newly hired engineers as potential participants, as well as managers representing a variety of engineering work groups across the organization.

The HR managers identified potential participants and recruited them for this study. Altogether, 30 newly hired engineers (17 new graduates and 13 new hires with previous job experience) and 6 managers agreed to participate. This study focused on the 17 new graduates and 6 managers. The newcomers were recent engineering graduates who had begun working in their first engineering jobs within the previous 6–18 months. The managers in our sample supervised work groups of approximately 8–20 engineers and had experience with supervising newcomers starting work in their groups.

16.2.3 Data Collection

The researcher interviewed each participant using a semi-structured interview format designed to collect a participant's experiences related to learning, working, and interacting during the start of a new job. This allowed the interviewer to deeply probe the participants' responses. Interviews with the newcomers employed a "critical incidents" approach (Ellinger and Watkins 1998; Flanagan 1954) where the interviewer asked participants to recall and describe (a) one to two recent projects (incidents) assigned to them and how they learned to work through the assignments and (b) one to two recent situations (incidents) in which they learned something about their roles and the socio-cultural aspects of their work. For each incident, the newcomers were asked to describe their experiences on the job and interactions with others in the organization.

Interviews with the managers focused on their perceptions of the socialization process, as well as their practices for socializing newcomers. Also following a critical incidents approach, I asked each manager to describe specific incidents they experienced related to newcomers learning and mastering their new jobs, as well as integrating into the organization.

The interviews lasted from 45 to 90 min and took place at the participants' place of work. They were recorded and later transcribed verbatim. The researcher checked the transcriptions for accuracy and discussed preliminary findings with many of the participants for additional feedback and confirmation.

16.2.4 Data Analysis

The interview transcripts were analyzed using qualitative data analysis procedures prescribed by Miles et al. (2014) and Strauss and Corbin (1998), as well as a constant comparative method (Glaser and Strauss 1967). Generally, the analyses followed an iterative three-step process:

1. Carefully read the transcripts and identify statements describing newcomers' experiences of learning to work in the organization.
2. These statements were coded using the open-coding process described by Strauss and Corbin staying close to the participants' language.
3. The open codes were sorted into categories describing the experiences of newcomers and managers regarding the socialization process.

Using the constant comparative method (Glaser and Strauss 1967; Strauss and Corbin 1998), the interviewer briefly analyzed interview notes as the interviews were collected and adjusted subsequent interviews based on emerging concepts and insights. Also, during coding, codes were combined when sufficient overlap existed and then reapplied to all the interviews. I performed this systematic data analysis process for both the newcomer and manager transcripts.

16.3 Findings of New Engineers' Experiences of Work

A holistic view of a practice as an occupational community provides a deeper understanding of the ways that people live and work with and within their communities (Corradi et al. 2010; Van Maanen and Barley 1984). Although it is difficult to isolate a particular practice from other practices or from the embedding organizational context, for analytical purposes the following describes particular practices organized at the individual, group, and organizational levels of analysis.

16.3.1 Practical Experiences at the Individual Level

Typically, there are conventions that specify what legitimate practices of individuals are in an occupational community. Especially in the professions, there are shared beliefs, values, and codified procedures that govern the thinking and behaviors of individual members of the community. The newly hired engineers in this study generally shared the beliefs and values about engineering they learned in school – mostly focused on engineering science (Trevelyan 2014). As they transitioned into the workplace, their engineering beliefs and values formed in school met with, collaborated and conflicted with the beliefs and values of business and the sociocultural organization as a whole.

A common belief and value held by newly hired engineers in this organization was the way in which one learned in school to "think like an engineer". This way of thinking was typically described as a rigorous, scientific method of solving problems. When talking about what separates engineers from non-engineers in the organization there was a perception among the newcomers that engineers have a uniquely powerful way of problem solving, most closely aligned with science and mathematics. This way of thinking was also characterized by new engineers as the essence of "real engineering work" in contrast to other aspects of their work such as attending meetings, managing projects, presenting information, and following organizational procedures.

The engineering way of thinking developed from the educational experiences of engineering students in an earlier stage of their professional socialization (in the academy). The most common description of thinking like an engineer drew upon the traditional scientific method described by new engineers as a sequential process of (a) organizing, defining, and understanding a problem; (b) gathering, analyzing, and interpreting data; (c) documenting and communicating the results. For example, one new engineer described his work: "This was me, go out in the vehicle, collect a bunch of data, find the problem in these data, look at the software, see how the software says it should have worked, and then fix the software". Practicing this process in the context of this organization also required that the engineer manage the problem-solving process (the three steps above) using project management processes and tools to maintain standards, meet budget constraints and deadlines, and most of all, coordinate the process among multiple stakeholders and peers in the organization (Korte et al. 2008).

When enacting this way of thinking in this organizational context new engineers described two unexpected factors affecting the problem solving process. They described the increased ambiguity and complexity of practicing engineering in a business organization and the increased influence of other people, including non-engineers, in the problem-solving process. New engineers considered the collection, manipulation, and analysis of data to be the "real work" of engineering and typically described the management and collaborative aspects of the process as non-engineering work.

Occasionally, managing projects also required they interact with non-engineers in the organization. The new engineers typically described this interaction as the interface of engineering and the "business side" of the organization. Even those newcomers that had previous work experience held to the "us and them" perceptions that the business people worked differently and had different goals from the engineering people. The engineers generally described the differences between the two groups as those focused on technical aspects of creating and making products and those focused on the selling and profitability of those products. One new engineer described the difference between the engineering and business sides of the company this way, based on his observation of engineers as managers in the engineering side of the company:

> It seems that the more you get into management, they're worried about managing people and doing all these other things, and then it seems like their core job responsibility isn't engineering any more, once you get so high ... There's a degradation I would say the higher you go ... Well they're worrying about more, I guess they'd be worrying more of the business side of it as opposed to the engineering side.

When asked for more specific examples he said,

> I guess like the business side would be more like – how many headcount do we need increased? Who is going to be working on what project? And the engineering side of it would be more like – my specific project gives you benefit XYZ, you can turn with a tenth of a G more lateral acceleration. You can get zero to 60 in 0.5 seconds faster. You know? And the how of doing that would be more of the engineering side. How does that affect your vehicle? What impact does it have? And they [*managers*] worry less and less about those things.

Asking new engineers what was the difference between their engineering practices in school and engineering on this job illuminated an important description of the practice of engineering in this business organization. For example, one new engineer described the difference between the problem solving model learned in school and the problem solving process in practice;

> I mean in school it's very textbook. They always try and model everything in a mathematical sense in school. And in the real world, it's a lot more difficult to model things. It's just there's a lot more variables involved and there's the unsurety too of whether or not you're modeling it right. Are you following the right procedures and principles?

Another new engineer described her experiences as:

> I think school was more like a technical thing, like where you learned equations ... Where now it's more like a logical sort of brainstorming, think through stuff, you know, sort of thing. It's more of a hands-on thing where you kind of see it and you're taking measurements or taking a part on and off. Or you know it's not fitting right but you don't know why and there's no mathematical formula you could use like you would in school to solve this problem.

Workplace problems are "ill-structured and complex because they possess conflicting goals, multiple solution methods, non-engineering success standards, non-engineering constraints, unanticipated problems, distributed knowledge, collaborative activity systems, the importance of experience, and multiple forms of problem representation" (Jonassen et al. 2006, p. 139). Along this line, another new engineer described the problem solving process, "Well, a lot of the problem solving here seems to be on the people side. Getting who you need, when you need, and knowing who knows what ..."

Trevelyan (2014) claimed that "Collaboration is the central activity in engineering" (p. 189). Furthermore, he stated that engineering practice only works because people collaborate and the quality of engineering depends on the quality of the social interactions facilitated through communication. Communication among the people in an organization is more than exchanging information – it is also a means of building relationships and making sense of things (Korte 2010; Trevelyan 2014).

There were also notable differences beyond the problem solving process regarding the complexity and ambiguity of engineering work in the business context or the so-called "real world". Bucciarelli and Kuhn (1997) described engineering work as the combination of object work and social process. Object work is reductionist by nature – striving for the one right answer – derived from the application of scientific principles. The object work of engineering as a science prefers designs and models that are "fixed, repeatable, stable, unambiguous and internally consistent" (p. 212). The social process of engineering entailed more qualitative, ambiguous, ill-structured problems that could be modeled and solved in multiple ways (Jonassen et al. 2006). It was challenging for newcomers to accommodate and work with this inherent ambiguity and complexity in which object work was embedded.

One of the work group managers described how she instructed newcomers to think beyond their individual jobs and consider the larger social system of the work.

> You've got to worry about your job, but worry about other things beyond your job. Like worry about how your job affects everybody else and what else you could do to make it work [*better*]. … You should think about how the person feeding into you, what they're providing and how could you work with them to make that more clear? And then, the person receiving what you're doing, how can you improve on that?

Many of these new engineers identified themselves as, or aspired to be, master problem solvers and their experiences in the organization included greater levels of complexity, ambiguity, and uncertainty than they expected. In these more ambiguous and socially driven situations they often looked to their coworkers in the work group for advice about the way things were to be done.

16.3.2 Practical Experiences in the Work Groups

At the group level of practice, there are shared models, tools and rules that help people interact by setting expectations and establishing routines (Feldman and Orlikowski 2011; Nicolini 2013; Schatzki 2001). Among the new engineers this was the level of interaction that presented the most surprises and difficulties in learning and performing. New engineers reported that they needed to learn how to define problems, collect and interpret data, and communicate the results in the manner preferred by the group. The methods of engineering they learned in school were variously interpreted and enacted in the contexts of their immediate work groups.

Even within the engineering community there were noted differences between the use of procedures and tools, for example one new engineer described the tension between two groups of engineers having different preferences for computational or physical data generation and analysis.

> We've been fighting, us CFD [*Computational Fluid Dynamics*] engineers, to a certain extent, our managers and our directors as well, has been fighting this assumption that CFD is not good for anything. And I'm on a project right now and I'm kind of fighting it too. Where they're using CFD for certain things but they're not willing to trust the numbers on the other sense. [*Interviewer: When you say they, who are they?]* It's more of the people actually that's been used to working on the physical side.

The extent of the social and political dynamics among groups was relatively surprising. There were also more blatantly political conflicts between engineering groups as when this new engineer described his experiences working with two groups, each trying to blame a problem on the other group.

> Like our groups' trying to prove the point to platform [*another work group*]... Okay, platform, you know what you're doing, we know what we're doing, we're going to prove that you're wrong. And it was like a battle of bullies... It was two separate camps trying to show that the other one was at fault and we're not meeting our economy targets because you didn't meet your requirements.

Many of the new engineers in this study described their unexpected realization of the importance of building relationships with others in the organization. They knew that others were important sources of information, but the extent of relationship building went beyond information gathering. As one newcomer reported,

> . . . if they don't think you're a priority or your work's priority, you'll be on the back burner for a year on something. And so you'll learn that you've really got to network and really learn people around here and really, really get to know them on a personal level and earn their respect.

The importance of interpersonal relations was typically within the work group rather than across groups.

> And we're all working on the same vehicles and there's interaction with them [*other groups*], but on the business level, on the technical level, rather than on a person's level. Within the group there's a lot of personal connection.

The relations among engineers varied by group. Some groups were very collegial and supportive of newcomers and others were more difficult. For example, two different newcomers reported two different experiences with groups in the same company.

> At first it was a little worrisome, if you would click with these people and get along. And if you didn't, 50 hours a week of trying to deal with people who don't get along would be a pure nightmare. But it only took minutes before people would stop over and introduce themselves and say hi and ask, 'Do you want to go out to lunch? You want to go to volley ball after work? Very friendly people. I was just like instantly accepted as one of the group and that was that.

In contrast:

> I've been there a year and I don't feel completely comfortable with everybody I work with, because I think you have a lot of engineers that are very into their work and they kind of shut the world off around them... They're approachable, but you kind of get the feeling like – don't bother me. You can go ask them questions and stuff like that, but then their cell phone rings or something comes up and then it's kind of like – I have to take this call or I have to do something else. So you kind of, there's this feeling of – ask questions but don't take too much of my time... Maybe that's how business goes or something. It's just get to the point, ask me the question, leave and fine..., I guess maybe it's this feeling of in school they teach you all about this teamwork effort. In business it's all about teamwork and working together. But then you come out here and I don't feel like I'm part of a team, I don't feel like there's any kind of teamwork thing. Everybody's got their projects and that's all they're focused on is they need to take care of this project and they need to do this and – don't bother me. I work in a group, and essentially that is sort of a team, but there isn't really like a team – I don't really feel like a team atmosphere like we're all working towards something together.

Coworkers were an important resource for helping newcomers make sense of various ambiguous situations. As one new engineer reported, "I was asking my coworkers a lot of those type of questions. Like, why are we doing this? What exactly is this doing? You know, just like getting more explanation on why we're doing that stuff."

Arguably the work group was the most important context in the organization for newly hired engineers. In this study, the work group varied in size from 8 to 20 people and it was the primary context in which the newcomers learned and worked in the organization. Within the context of the work group, one of the most important factors was the quality of the relationships among the members of the group, which directly influenced the quality of learning, performance, and job satisfaction. Also, recurring experiences important to newcomers related to the quality of mentoring they received (if any), the sociability and camaraderie of coworkers and managers, and the opportunities for meaningful work (Korte 2009). Along with the technical work they were assigned, these experiences formed the major part of their work as new engineers in the organization.

Experiences outside of their local work group (including non-engineering groups) were more indirect and mostly entailed the decisions from marketing or purchasing described below in the experiences at the organizational level. A very important member of the work group was the manager. Typically they served as the link for newcomers to the “business side” of the organization. The quality of newcomers’ relations with their managers was a major factor in their learning, performance, and job satisfaction. Generally, newcomers looked to their coworkers for advice and help learning the tasks of their jobs and they looked to their managers for advice and help learning the structure of the larger organization and how their work fit into the business of the organization.

16.3.3 Practical Experiences of the Organization

Although the majority of newly hired engineers’ experiences were within the work group setting, there were important experiences beyond their groups that were more organization wide. These tended to be business-oriented practices pertaining to customers, marketing, regulations, and organizational management. For example, one new engineer described the corporate push to cut costs and reduce the time spent on vehicle development.

> There’s always a push for things to take less time. Right now they want to push all the physical testing to analytical testing and get it down to hours. They don’t even want to set up. So there’s a lot of push that we don’t need to build bodies, buy bodies, have technicians, have test engineers.

There were also the more expected differences between functional activities in the organization. One typical story described differences concerning decisions about parts specified by engineering and ordered by purchasing.

> Another thing too that I learned was the pricing for this stuff. I hear people ask, and I’ve asked myself – why does the company do it this way? ... well, it’s cheaper. Like, well come on, it’s a penny cheaper. But I’ve learned that a penny cheaper on a several-hundred-dollar item, that’s a big thing. And I would never have thought that. They will buy it from Company B instead of Company A if it’s one penny cheaper, seriously.

Another important organizational experience for new engineers pertained to job boundaries. While it was an expectation from managers that newcomers should take initiative and not wait to be told to do something, this expectation was limited by union rules, others’ job responsibilities, and tacit expectations. Newcomers learned what practices were appropriate and which were not, and they learned these rules mostly by trial-and-error. As one newcomer recounted, “Be very careful about knowing whose role is what. I learned people are, especially with the times now, are very sensitive about whose work is who.” Being new to the organization was usually an acceptable excuse for overstepping one’s bounds.

There were also comments regarding the experiences of organizational procedures – such as the paperwork used to monitor work practices. Some newcomers marveled at the complicated procedures for seemingly simple tasks. For example,

> there's a hell of a paper trail to things... It's just like I want to run a test out in the test lab but I've got to write a PER or a Procedure Execution Request, and that goes to my boss and he's got to be okay that I want to do this. And this has to go to the manager of all the labs, so it goes into their timing. And then it goes down to the manager of a specific lab so it goes into his timing. And then it goes down to the manager of that lab, off to the supervisor of the technicians. And then it comes back to my manager, and finally comes back onto my plate where I'm now responsible. But generally days and days for all these... Sometimes a week and a half, two weeks. And they have to see it and read it, approve it or reject it. With a rejection, it comes back to me and they'll say – well, you really need to be doing this. And I add that into the plan that's got to go back through that loop.

When asked what he thought of all this paperwork he replied,

> It didn't bother me too much... this is very typical of business, that there's a lot of procedure. A lot of it is focused around the fact that without some procedure and some level of documentation to actually simplify things, upper management is not going to have a clue. And they can't really run the company without the simple facts, but they can't get the simple facts unless somebody at the bottom puts this in simple form and it goes up.

Practicing engineering within the larger context of the business organization also entailed making an impression on upper managers. New engineers quickly learned the importance of getting known by the directors above their groups.

> What I've been told is the promotion process within [*company*]... all the directors would get together, put a face on a screen. What do you know about this guy or person? Do you think they're worth promoting or not promoting? And they just go through everybody... They all vote ye or nay, and the other director moves to their people and they all vote ye or nay. So they go around all these people. And from that you get kind of the people that they think should be promoted. But the thing is it's all face time. So you may have somebody that's tremendously competent but because they've never really had to interact, [*with* directors] they're never going to get anywhere.

This brief sampling of experiences reported by new engineers learning to practice engineering in a business organization illustrates how newly hired engineers learn that engineering practice is largely a social process interacting among themselves, as well as other groups – all embedded in a social-organizational context (see Fig. 16.1). Whether or not they appreciate the social nature of engineering or view it as non-engineering work is part of the developmental process of learning to practice engineering in an organizational context.

16.4 Discussion

The nexus of engineering and business can be examined by looking at this relationship as the interactions between two different occupational communities or professions – engineering and management – embedded in an organizational setting. This framework displays a multitude of variations from one organization to another. Specific to engineering business firms, individual organizations can be situated on a continuum ranging from a predominately engineering organization engaging in business activity to a predominately business organization engaging in engineering activity. Thus, the relationship between business and engineering has many possibilities based on the nature of the relationship between these two occupational communities, the nature of the organization's social systems, and the environment in which these organizations operate.

The general labels of business and engineering tend to gloss over the details of what workers do as members of these communities (Van Maanen and Barley 1984). Business and engineering activities are far more variable and idiosyncratic than the labels imply, and much of this variability derives from the organizational contexts in which business and engineering interact. Based on the reports of newcomers and managers in this study and others (cf., Johri 2012; Trevelyan 2014), engineers, especially experienced engineers incorporate many stereotypical business practices in their work (e.g., negotiation, influence, financial and market analyses, management, and so on). Thus, the boundaries between business and engineering are often blurred in practice.

From the analysis of the interviews with new engineers and managers in this organization there emerged three general domains of work practices: engineering oriented, business oriented, and organizationally oriented work. Conceptually and culturally, engineering and business are considered to be different occupational fields with different goals, beliefs, and views of the world, however both are practiced in organizational contexts requiring social interactions and interrelations to accomplish their goals and the goals of the organization. Thus, the social activities of collaboration, cooperation, and conflict inherent in the workplace are manifestations of the social-organizational contexts in which engineering and business are practiced (See Fig. 16.1).

Hatmaker (2012) and others (Korte 2009; Trevelyan 2014) pointed out that the distinction between the technical and the social in engineering is unrealistic and misleading. In organizational contexts, engineers are necessarily dependent on and entangled with social activity and other occupational communities to do the work they do. It is difficult to disentangle social activity from any other work activity in organizations. The same can be said for business professionals. Furthermore, one could argue that much (if not all) of the work of engineering, business, and all other occupational communities is socially constructed and socially conducted in organizational settings.

In addition to variations in the way different occupational communities practice their work, how people practice their professions varies by different social-organizational settings. Thévenot (2001) described different configurations or patterns of practices at different levels of analysis (individual, group, or organization). These differences included the relationships between people and their occupational and material environments. At the individual level of practice people generally have more flexibility to personalize or customize occupational practices for their convenience. For the new engineers in this study, working individually (although rare) mostly entailed the more technical practices for which they were trained in school – although they had to customize their practices to fit the practical contexts of their jobs. For example, one new engineer described his way of working through an assignment,

> A lot of trial and error. When you first start, you're really not sure how to do it, but you have to just... What I've found is that you have to put down something to see how it works, because you can think about how to do something for days, but you don't quite realize if it's good or bad until you actually do it.

At the group level of analysis, the work of the individual must now conform to the expectations and norms of the group having a more conventional and codified view of their occupational practices in order to facilitate collaboration or cooperation among the members of the group. An important component of this level is the individual's use of norms and mental models to monitor and predict interactions among their coworkers, as well as members of other groups. One new engineer recounted his difficulties when he had to follow the procedures of other groups to get things done.

> It's like when I do things on my own and I grab people and we try to figure things out, we make the plan and everything is smooth. But then when [*other*] people are sticklers of the process, you run into a lot of problems.

He continued on about a potential crisis for one of his new programs and described how the group came together to resolve the issue. It also illustrates the blending of business and engineering practices in handling this problem.

> Luckily, I have a very proactive program level validation engineer who watches all of the validation groups for his car program. And he, about once a week, goes through and does an audit on every single system we have… He goes through it and he came across this work order that went through for an '09 in '06, [*three years early*] and… he started digging and he came to my desk to say – hey, this happened. It's in your area, that goes on a front closure. He said – call everybody and anybody. Get a team of 30 people together, get this handled and get it handled now. Otherwise, you know ... Make sure we get this part validated. And he explained the problem with the guys, he's like – we don't have $600,000 to untool and we need to get people together to figure out where we stand. How bad is this? What is it going to take to validate this part? And if it's not validated, what is it going to take to make sure it can be validated so we don't have a couple hundred thousand unhappy customers out there?

Most of the experiences of these new engineers occurred at the group level, which was the primary context of their practice as engineers. In this context they had the benefit of some level of shared understandings and expectations of work with their coworkers and managers focused on knowing "how to think like an engineer" and follow the engineering way of doing things (Godfrey and Parker 2010). Typically, this shared understanding was largely about technical concepts and practices. The greatest difficulty reported by these newcomers had to do with the inherent social nature of technical practices, including interactions with others within and beyond the group.

The organizational-level can be the most socially regulated level of practice and relies on conditions of legitimacy, regulations, and socio-cultural norms as important influences on practices across larger social groups (Thévenot 2001). Organizational level interactions were minimal for these new engineers and often were mediated and interpreted by their managers or other senior members of the group with extensive organizational experience. Several reports from newcomers and managers described their interactions in which the objective was for the manager to explain to the newcomer how their work fit into the larger organization and why the management of the organization was practiced in the way it was. These discussions were often focused on the business practices of the organization and how engineering work fits with the business of the organization.

How an occupational community, such as business or engineering, views the world derives from the preferred assumptions, values, and beliefs, which make up the institutional logic of the community. Institutional logics are the organizing principles that rest on different frameworks of meaning and knowledge (Kilduff et al. 2011). Different logics provide different bundles of assumptions and practices that prescribe the appropriate ways of thinking and acting in a community. In different organizations, different logics will likely operate to pursue different problems, accept different metrics, and prefer different methods of action.

The institutional logic of engineering is anchored in a fundamental hierarchical view of reality with universal laws based on math and science at the top, followed by more localized situational theories and principles (Bucciarelli 2003; Godfrey and Parker 2010). Near the bottom of the hierarchy is the social world. While the evidence from research on engineering practice (Korte 2009; Trevelyan 2014) challenges the validity of this hierarchy in practice, it seems to persist in the minds of engineers and others as the highly regarded way of being an engineer (Godfrey and Parker 2010). The world of practice is predominately a social world and this was a major challenge for many of the new engineers as they learned to apprehend and accommodate the social norms of the group into their work and integrate themselves into the social fabric of the work group.

Based on their empirical studies of engineering practice Trevelyan (2010, 2014) and Korte et al. (2008) found that practicing engineers do not consider much of their work on the job to be "real engineering." Real engineering work was considered to be the work of engineering science – a technical endeavor (Godfrey and Parker 2010; Trevelyan 2014). A broader view of engineering practice, based on empirical evidence, included important processes of communication, negotiation, coordination, legitimation, conflict, power, politics, management, and organization, as well as the core technical practices most often defined as engineering (Korte et al. 2008; Trevelyan 2010).

There is an inherent institutional tension between engineering as technical work and business work. Technical workers generally value creative work, the quality of work, and long-range research goals versus the value of profitability driving business management (Creighton and Hodson 1997). The institutional logics driving the business community are generally anchored in a fundamental rational, economic view of reality with universal laws based on economics at the top, followed by more localized, situational theories and principles of organizational behavior, management, marketing, production, and so on.

Traditional organizational forms of business have been evolving from hierarchical production models to more dynamic and fluid models based on collaborative networks and communities (Miles et al. 2009). Organizations are evolving due to the increasing virtualization of work, open source work practices, decline of organizational hierarchy, generation Y values, tumultuous global markets, and business sustainability (McDonald 2011). The newer dynamics embrace an environment of innovation and entrepreneurship driven by rapidly and continuously developing technology and markets. Miles et al. (2009) described the growing importance of innovation in business and identified the characteristics of collaboration and trust among employees as key to their success. Granted that business organizations are affected to different degrees by these institutional and environmental impacts, however the importance of engineering and science to technology innovations and entrepreneurship is a key resource in these newer forms of organization.

Along with the rise of engineering driving innovation in the marketplace is the rise of entrepreneurship as a valuable skill for innovators. Since innovation is inherent in much of the value of engineering work, entrepreneurial knowledge and related business skills are becoming valuable competencies for engineers. Furthermore, policy-makers view innovation and entrepreneurship as critical factors in keeping economies vital and competitive (National Science Foundation 2010). The national and global emphases on entrepreneurship and innovation are blurring the boundaries between the engineering and business communities.

Following Van Maanen and Barley's (1984) admonition to look closely at what actual people do in the workplace, this essay proposes that we go beyond a general idea of the relationship (the nexus) between engineering and business. As they stated, the interactions of occupational communities in organizations provide a helpful lens through which to view the characteristics of organizations relying on business and engineering practices for their survival. From this perspective, one can articulate three types of communities: engineering, business, and the organization. Each of these three depend on and are constituted by the interactions of the other two. An organization by definition is a group of people working within predominantly social structures and processes; engineering by definition produces solutions to or manages problems of markets and societies; and business by definition manages the commercial needs of the organization. There is not much to business or engineering without the social organization (Korte et al. 2008; Trevelyan 2014). Therefore, wherever engineering or business operates as an organization they either must accommodate and attend to the social nature of the organization along with the occupational practices unique to their individual professions. The distinctions between business and engineering communities, as well as among other occupational communities, are mostly disconnected abstractions that tend to disappear in the chaos, complexity, and busyness of organizational work.

References

Anderson, K. J. B., Courter, S. S., McGlamery, T., Nathans-Kelly, T. M., & Nicometo, C. G. (2010). Understanding engineering work and identity: A cross-case analysis of engineers within six firms. *Engineering Studies, 2*(3), 153–174.

Barley, S. R. (2005). What we know (and mostly don't know) about technical work. In S. Ackroyd, R. Batt, P. Thompson, & P. S. Tolbert (Eds.), *The Oxford handbook of work and organization* (pp. 376–403). Oxford: Oxford University Press.

Brown, J. S., & Duguid, P. (2001). Knowledge and organization: A social practice perspective. *Organization Science, 12*(2), 198–213.

Bucciarelli, L. L. (2003). *Engineering philosophy*. Delft: Delft University Press.

Bucciarelli, L. L., & Kuhn, S. (1997). Engineering education and engineering practice: Improving the fit. In S. R. Barley & J. E. Orr (Eds.), *Between craft and science: Technical work in U.S. settings* (pp. 210–229). Ithaca: Cornell University Press.

Chao, G. T., O'Leary-Kelly, A. M., Wolf, S., Klein, H. J., & Gardner, P. D. (1994). Organizational socialization: Its content and consequences. *Journal of Applied Psychology, 79*(5), 730–743.

Cooper-Thomas, H. D., & Anderson, N. (2006). Organizational socialization: A new theoretical model and recommendations for future research and HRM practices in organizations. *Journal of Managerial Psychology, 21*(5), 492–516.

Corradi, G., Gherardi, S., & Verzelloni, L. (2010). Through the practice lens: Where is the bandwagon of practice-based studies heading? *Management Learning, 41*(3), 265–283.

Creighton, S., & Hodson, R. (1997). Whose side are they on? Technical workers and management ideology. In S. R. Barley & J. E. Orr (Eds.), *Between craft and science: Technical work in U.S. settings*, *Chapter 3*. Ithaca: Cornell University Press.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.

Ellinger, A. D., & Watkins, K. E. (1998). Updating the critical incident technique after forty-four years. In R. J. Torraco (Ed.), *Academy of Human Resource Development Conference*. Oakbrook.

Feldman, M. S., & Orlikowski, W. J. (2011). Theorizing practice and practicing theory. *Organization Science, 22*(5), 1240–1253.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin, 51*, 327–358.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York: Aldine de Gruyter.

Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education, 99*(1), 5–22.

Hanneman, L., & Gardner, P. (2010). Under the economic turmoil a skills gap simmers. (Research Brief 1-2010). Retrieved from Michigan State, Collegiate Employment Research Institute website: http://wizards/wpcontent/uploads/2010/01/skillsabrief1-2010.pdf

Hatmaker, D. M. (2012). Practicing engineers: Professional identity construction through role configuration. *Engineering Studies, 4*(2), 121–144.

Johri, A. (2012). Learning to demo: The sociomateriality of newcomer participation in engineering research practices. *Engineering Studies, 4*(3), 249–269.

Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139–151.

Jones, G. R. (1983). Psychological orientation and the process of organizational socialization: An interactionist perspective. *Academy of Management Review, 8*(3), 464–474.

Kammeyer-Mueller, J. D., & Wanberg, C. R. (2003). Unwrapping the organizational entry process: Disentangling multiple antecedents and their pathways to adjustment. *Journal of Applied Psychology, 88*(5), 779–794.

Kilduff, M., Mehra, A., & Dunn, M. B. (2011). From blue sky research to problem solving: A philosophy of science theory of new knowledge production. *Academy of Management Review, 36*(2), 297–317.

Korte, R. F. (2009). How newcomers learn the social norms of an organization: A case study of the socialization of newly hired engineers. *Human Resource Development Quarterly, 20*(3), 285–306.

Korte, R. (2010). First, get to know them: A relational view of organizational socialization. *Human Resource Development International, 13*(1), 27–43.

Korte, R. F., Sheppard, S., Jordan, W. C. (2008). A study of the early work experiences of recent graduates in engineering. *Proceedings of the American Society for Engineering Education Conference, 2008.* Pittsburgh.

Korte, R., Brunhaver, S., & Sheppard, S. (2015). (Mis)interpretations of organizational socialization: The expectations and experiences of newcomers and managers. *Human Resource Development Quarterly, 26*(2), 185–208. https://doi.org/10.1002/hrdq.21206.

Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). *Engineering change: A study of the impact of EC2000*. Baltimore: ABET.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills: Sage.

Louis, M. R. (1980). Surprise and sense making: What newcomers experience in entering unfamiliar organizational settings. *Administrative Science Quarterly, 25*, 226–251.

McDonald, P. (2011). It's time for management version 2.0: Six forces redefining the future of modern management. *Futures, 43*, 797–808.

Merriam-Webster's online dictionary. (n.d.). Retrieved from http://www.merriam-webster.com

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). Qualitative data analysis: A methods sourcebook, 3rd ed. Thousand Oaks, CA: Sage Publications, Inc.

Miles, R. E., Miles, G., Snow, C. C., Blomqvist, K., & Rocha, H. (2009). The I-form organization. *California Management Review, 51*(4), 61–76.

National Science Foundation. (2010). *The role of the National Science Foundation in the innovation ecosystem (White Paper)*. Washington, DC: National Science Foundation.

Nicolini, D. (2013). *Practice theory, work, and organization: An introduction*. Oxford: Oxford University Press.

Passow, H. J. (2012). Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education, 101*(1), 95–118.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks: Sage.

Radcliffe, D. F. (2006). Guest editorial: Shaping the discipline of engineering education. *Journal of Engineering Education, 95*(4), 263–264.

Schatzki, T. R. (2001). Introduction: Practice theory. In T. R. Schatzki, K. K. Cetina, & E. von Savigny (Eds.), *The practice turn in contemporary theory* (pp. 1–14). London: Routledge.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field*, *The Carnegie Foundation for the Advancement of Teaching*. San Francisco: Jossey-Bass.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks: Sage.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks: Sage.

Thévenot, L. (2001). Pragmatic regimes governing the engagement with the world. In T. R. Schatzki, K. K. Cetina, & E. von Savigny (Eds.), *The practice turn in contemporary theory* (pp. 56–73). London: Routledge.

Trevelyan, J. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175–195.

Trevelyan, J. P. (2014). *The making of an expert engineer*. Boca Raton: CRC.

Van Maanen, J., & Barley, S. R. (1984). Occupational communities: Culture and control in organizations. *Research in Organizational Behavior, 6*, 287–365.
Van Maanen, J., & Schein, E. H. (1979). Toward a theory of organizational socialization. *Research in Organizational Behavior, 1*, 209–264.
Vinck, D. (Ed.). (2003). *Everyday engineering*. Cambridge, MA: The MIT.
Weick, K. E. (1995). *Sensemaking in organizations*. Thousand Oaks: Sage.
Wenger, E. (2000). Communities of practice and social learning systems. *Organization, 7*(2), 225–246.
Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks: Sage.

Russell Korte Associate Professor of Human and Organizational Learning at the George Washington University. Dr. Korte studies the socio-cultural systems in organizations and their effects on learning and performance in school and the workplace. This work focuses on the professional socialization of engineering students, faculty, practicing engineers, medical students, and teachers. Prior to GW, Korte was at Colorado State University and the University of Illinois at Urbana-Champaign where he helped redesign the first year engineering program as a Fellow with the Illinois Foundry for Innovation in Engineering Education and was a member of the Academy for Excellence in Engineering Education – a faculty development program at the University of Illinois. Earlier, he was a research assistant for the Center for the Advancement of Engineering Education at the University of Washington. Past work experiences include several years in business and consulting. Additional research interests include theory, philosophy, social science, workplace learning and performance, socialization, professional education, and organization studies.

Part IV
Engineering and Business Education

Chapter 17
Business in Engineering Education: Issues, Identities, Hybrids, and Limits

Mike Murphy, Pat O'Donnell, and John Jameson

Abstract This chapter explores how undergraduate engineering students are broadened in their education through the inclusion of non-core engineering content, such as business modules, in their curriculum in order to develop critical thinking skills and self-knowledge of what it means to be an engineer. The goal of the chapter is to provide a commentary on the level of interaction, from design of courses to design of curricula, between business faculty and engineering faculty, and the results of that interaction. This chapter sets out to (i) explore whether there appears to be a place in engineering education curricula for reflective critique of assumptions related to business thinking, and why; (ii) discover what kinds of business issues are reflected in engineering education curricula, and for what purpose; (iii) explore the degree of business hybridization in engineering degree programs; (iv) ask who teaches business issues within engineering education? To this end a taxonomy of engineering enlightenment is proposed, and this is used to discuss evidence of broadening within engineering curricula. The approach adopted is to: review all relevant engineering degree programs in Ireland, based on their publicly available program information; examine the accreditation reports for these same programs; and then survey deans from colleges or schools of business to examine whether the business college/school is involved in the education of engineering students in the institution or university. If yes, how the business college or relevant business faculty are engaged in the design of engineering curricula. In order to enable a comparative discussion, the chapter will focus on Irish engineering programs that seek accreditation from Engineers Ireland for professional

M. Murphy (✉)
Academic Affairs, Digital & Learning Transformation, Dublin Institute of Technology, Dublin 2, Ireland
e-mail: mike.murphy@dit.ie

J. Jameson
Dublin Institute of Technology, Dublin 2, Ireland
e-mail: john.jameson@dit.ie

P. O'Donnell
Technological University Dublin, Dublin 7, Ireland
e-mail: pat.odonnell@tu4dublin.ie

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_17

engineering. A number of hybrid engineering programs of study are also explored, and their apparent strengths discussed, including hybridity limits.

Keywords Mitcham · Veblen · Engineering education · Business · Social sciences · Accreditation · Self-reflection · Classification of engineering enlightenment · Curriculum broadening

17.1 Introduction

> .….by the time we understand the pattern we are in, the definition we are making for ourselves, it's too late to break out of the box. …Yet the definition we have made of ourselves is ourselves. To break out of it, we must make a new self. But how can the self make a new self when the selflessness which it is, is the only substance from which the new self can be made?
>
> Robert Penn Warren, All the King's Men

Not long after the Great War, the American economist and sociologist Thorstein Veblen argued for a technocracy in which the welfare of humanity would be entrusted to the control of the engineers. "The material welfare of the community is unreservedly bound up with the due working of this industrial system, and therefore with its unreserved control by the engineers, who alone are competent to manage it," he stated, and thereby it was solely the engineers who could optimize and maximize its output (Veblen 1921, p. 44). But less than a hundred years later, the philosopher of technology Carl Mitcham cried *stop* and argued that "neither engineers nor politicians deliberate seriously on the role of engineering in transforming our world. Instead, they limit themselves to celebratory clichés about economic benefit, national defense, and innovation" (Mitcham 2014, p. 19). The greatest engineering challenge, according to Mitcham, is to cultivate "deeper and more critical thinking … about the ways engineering is transforming how and why we live" (ibid, p. 19). This is also in marked contrast to Ton Meijknecht and Hans Van Drongelen who explored the spirituality of engineering and who described the societal value of engineering as follows: "From early times, they have answered the needs of people not by building sentences, but by constructing machines or water managing systems, organizing storage and transport of goods and food supplies, offering cities the conditions to grow and make life good and comfortable" (2004, p. 449). The realization that, as a class, engineers are indeed transforming the world is a profound and sobering thought, and Mitcham's challenge that engineers must deliberate seriously on their role in this transformation deserves to be explored. This is compounded by his more-than-implicit criticism that the way the world is transforming and evolving is not desirable, to say nothing of optimal, that engineers have contributed through their activities of designing and constructing new structures, processes, and products to a quality of life, indeed to a way of living, that is not what it could be; that it is engineers as a class, who are responsible for over-promising the benefits of technology and under-delivering on a better society.

The world today, in the first quarter of the twenty-first century, is a complex system of interconnected and competing economies, political systems and cultures. It is a system which, by and large, has evolved to focus on unconstrained growth, and for which Mitcham despairs that "relatively few engineers, when invited to reflect on their professions, can do much more than echo libertarian appeals to the need for unfettered innovation to fuel endless growth" (Mitcham 2014, p. 20). In terms of future models, Richard Heinberg of the Post Carbon Institute argues that "economic growth as we have known it is over and done with" (2011. p. 1). He argues that going forward, only relative growth is possible, that "the global economy is playing a zero-sum game, with an ever shrinking pot to be divided among the winners" (*ibid*, p. 2). The absence of growth, he argues, does not necessarily imply a lack of improvement, and that within a non-growing economy the emphasis must shift from more consumption to better quality of life. Whether unfettered growth or no growth, both agree that a shift is required to examine and improve the society in which we live. But where the engineer sits in this society is becoming increasingly uncomfortable. Meijknecht and van Drongelen (2004) note that for engineers "the days of comfortable autonomy are over and done with. Engineers can no longer hide in the realms of science and technology and focus solely on the development of new technologies. As mediators between science and the world they live in, engineers have the task of finding ways to sustain and develop life in a balanced and adequate way by controlling and explaining the complicated processes in nature and human existence" (Meijknecht and Drongelen 2004, p. 450).

Engineering education concerns itself with useful learning: that engineering students are educated to do something with their learning – generally to solve problems through the development of technology, and thereby improve the world. "The question asked by engineers is not *what is the idea behind it? What is the concept? Where does this all stem from?* but *does it work?"* (*ibid*. p. 448). Useful learning embodies the duality of engineering education. According to Debora Johnson "Whenever you build something physical, you also build something social. Engineers are making society," she says. "They are making technology, but technology is society." (quoted in Kaplan-Leiserson 2015, p. 22). This is important in order to ensure that engineers are not just cogs on a wheel, but that they also are capable of thinking about the wheel that they are designing.

But Carl Mitcham's argument in a nutshell is that there is too much *use* and not enough *learning* in the typical undergraduate engineering program. Accepting the larger societal point about the need to examine how and why engineering is transforming how we live, and the individual point that the engineer should seek self-knowledge through reflection and self-examination, this chapter sets out to discover how engineering education broadens the engineering student. In particular, what kinds of non-engineering courses are reflected in engineering education curricula? We explore whether there is evidence that sufficient space has been allocated within engineering curricula for self-reflection and critical thinking on the ways engineering is transforming how and why we live. We do this by examining the elements of engineering education that can be considered as providing evidence of a broadening agenda, in particular an education that asks engineering students to examine societal impacts, innovation and entrepreneurship.

17.2 Classification of Engineering Program Enlightenment

Let us begin with the working assumption that engineers, as a profession, believe that they are more than merely expert cogs on a wheel. They also comprehend the wheel and the purpose of the wheel. There is a secondary question as to whether *all* engineers must have this broader understanding, but since in this chapter we are discussing the development of professional engineers, the simple answer for our purposes is *yes*. "Engineering programs like to promote innovation in product creation, and to some extent in pedagogy, yet almost never in critical thinking about what it means to be an engineer. How about engineers who can think holistically and critically about their own role in making our world and assist their non-engineering fellow citizens as well in thinking that goes beyond superficial promotions of the new?" (Mitcham 2014, pp. 19–20) We propose a hierarchical classification by which engineering programs may be examined in order to gain insight into the degree to which these programs develop this broader and critical understanding within their students (see Table 17.1). This Mitcham Classification of Engineering Program Enlightenment is proposed as an instrument to examine engineering programs, and is adapted from Mitcham's arguments to engineering schools about how humanities courses are justified in their ability to support the enlightenment of engineers.

The set of non-engineering programs has been broadened to include social sciences, which Mitcham accepts. We note in passing that the fields of the Humanities, Social Sciences and Liberal Arts are generally invoked when proposing either broadening or hybrid engineering programs. By using this Classification, the purpose behind a broadening course can be examined. Engineering programs can also be examined to see whether there is constructive alignment between the goal or aims of the program and the evidence of success in terms of the level (1 through 4) to which each program appears to be operating. We also note in passing here that in a commentary on Mitcham's article, Steen H. Christensen (2015, p. 22) observes that it is the dominant core-periphery distinction in engineering education that ensures that attempts to broaden the curriculum are doomed to fail. We explore this

Table 17.1 Mitcham classification of engineering program enlightenment

	Justification	Description	Effect
1	No justification	Engineers transform the world because they can	Engineering education is through the core disciplines of engineering
2	Instrumental justification	Engineers transform the world and they can communicate it clearly	Social Sciences courses can improve the communications skills of engineers
3	Enhanced Instrumental justification	Engineers transform the world and they can justify it rationally and contextually	Social Sciences courses can locate engineering projects within their broader social context
4	Intrinsic Value justification	Engineers transform the world and they can reflect on what it means for all of us	Social Sciences courses enable critical self-reflection on the meaning of life in a progressively engineered world

point later in discussing findings. Since the majority of engineering programs undergo accreditation of one form or another, then examining the process of accreditation and the evidence resulting from accreditation visits provides one means to apply the above taxonomy. A second is through a review of available information for each program.

17.3 Scope and Methodology

The scope of this review is all engineering programs in Ireland accredited for the educational level of professional engineer. To complete this review, every such program in Irish universities and Institutes of Technology (IoT) was identified. Publicly available information for each program was reviewed. Next, the accreditation reports of each program for the last 10 years were studied, i.e., from 2007 to 2016). By examining every relevant Irish engineering program, this review can comment on whether there is evidence of systemic approaches to a broadening agenda, whether there is evidence of institutional approaches, or evidence of broadening approaches only at the program level. This was followed by semi-structured interviews with deans and heads of business colleges, which were conducted to examine the degree to which engineering programs sought non-engineering support to teach subjects within the engineering curricula. Finally, some relevant selected data from the Irish Survey of Student Engagement (ISSE) are presented, and we discuss a small number of hybrid engineering degree programs.

17.4 Background

The majority of engineering graduates are educated to work in engineering organisations within engineering roles. It is self-evident to say that is why they are educated as engineers. Doctors are not educated to work as teachers, nor lawyers educated to work as clergy, so it is hardly surprising that institutions set out to educate engineers to work as engineers. Consequently the majority of engineering students are educated in accredited engineering programs with the clear expectation that as graduates they will be capable of functioning as engineers in the workforce. That many engineering graduates move smoothly over their careers from technical roles to non-technical roles (often management roles) is a positive statement on their educational and professional competence.

The debate continues within the engineering educational sector regarding the effectiveness of many programs in preparing graduating students for the changed world in which they will practice their profession. For example, Eileen Goold (2015, p. 215) asserts that “neither the engineering profession nor the educational system supporting it has kept pace with the changing nature” of what James Duderstadt (2008, p. 3) has described as the “knowledge-intensive society and the global marketplace". There is an evident need to build an expanded educational curriculum which better reflects the reality of the engineer's role in society.

For many undergraduate engineering programs the technical and mathematical sciences on which engineering courses are built often do not explain the landscape of practice (James Trevelyan 2013). As a consequence "many of the engineering students who make it to graduation enter the workforce ill-equipped for the complex interactions, across many disciplines, of real-world engineered systems" (Wulf and Fisher 2002, p. 35). The failure to adequately respond to such criticisms is undermining the educational experience of many student engineers and impacting on their career prospects beyond graduation. Many engineers are compelled to retrain, indeed to reinvent themselves, a relatively few years after graduation, in order to remain relevant and employable, and to obtain the broader perspective required in a more mature professional. While all professionals have to do this to a degree, it is a bigger and more difficult leap for engineers, particularly when their undergraduate education has given them too narrow a foundation.

The nature of many undergraduate engineering programs is that they are narrow and technical with little time or curriculum space for non-core content. The typical undergraduate engineering program is characterized by the "dominance of the applied engineering sciences at the expense of tacit knowledge, political, social and economic perspectives and ability to achieve practical results through other people is noticeably lacking in the students' engineering education (Goold 2015, p. 3). If engineering is to play its required role in society, then engineering needs to redefine its identity more broadly and engineering education needs to respond with a more comprehensive curriculum.

Part of the under provision can be explained by a lack of curriculum space on many undergraduate engineering programs. A greater problem however involves the lack of acceptance of the legitimacy of non-core engineering content by staff and students within engineering departments. Too many undergraduate engineering programs have failed to respond to the changing role of the engineer in society.

The failure to respond positively to the need to broaden the engineering curriculum has drawn the attention of many commentators. A warning has been sounded in some quarters suggesting that technical engineering skills are becoming commoditized, and as a consequence the graduating engineer would not be ideally suited to meet the requirements of the future labour market, which requires a degree of convergence between technological and non-technological skills (Grimson et al. 2008). The call for an engineering education response is growing. Some authors have predicted that if engineers do not accept hybrid engineering degree programs they will be constrained to purely technical work activities (Grimson et al. 2008).

There are calls to reconceptualize undergraduate engineering education to reflect the actual practice of engineering in its broader socially defined context. Trevelyan argues that "while technical expertise distinguishes engineers as an occupational group, socio-technical factors shape the landscape of practice" (Trevelyan 2014). Trevelyan further states that 'building a deep understanding of engineering practice into the curriculum has the potential to greatly strengthen engineering education (Trevelyan 2010). It has also been suggested that an engineer is a 'composite' person in that it is not only science and technology that is of concern but also ethics, law, the impact on society and environmental aspects being just a few of many legitimate concerns that impact on how an engineer functions (Grimson et al. 2008). Without a broadened educational experience many graduating engineers may struggle in terms of their employability despite their technical proficiency. These concerns represent a challenge for those responsible for the education and early development of tomorrow's engineer (Grimson et al. 2008)

In reviewing the work of an engineer Trevelyan (2014) concluded that a typical "engineering project is specified by client requirements, standards, regulations, social needs and environmental constraints and it has a project life cycle" – characteristics beyond the narrow domain of many undergraduate engineering programs. He concluded that "Engineers need to know it all: the engineering enterprise, explicit knowledge, procedural knowledge, implicit knowledge, tacit knowledge, contextual knowledge, engineering knowledge and technical knowledge in the workplace". (Trevelyan 2014)

Within industry, many companies describe the ideal graduate employee in terms of the T-shaped graduate, with an appropriate balance between the breadth and depth of the "T". See for example comments made by Tim Brown, chief executive officer of IDEO in an interview for Chief Executive (Hansen 2010). The vertical stroke represents the depth. In the case of the engineer the depth is, appropriately, in core science and technology. The horizontal stroke represents the breadth – the range of multidisciplinary knowledge and skills that provides an individual with the perspective and skillset necessary to critically and holistically assess their contribution and crucially to collaborate across disciplines. It appears that engineering academics overwhelmingly believe that their institutions compete with others almost exclusively on the technical excellence of their graduates. The feedback from industry on the actual graduates they employ, however, is that the main deficiencies lie in the breadth: engineering schools produce I-shaped graduates, while industry wants T-shaped graduates. When the voice of industry, with its ultimately commercial focus, is added to the general commentary, one is led to the conclusion that the modern world requires a more rounded engineer, with the rounding provided by multidisciplinary studies and personal development.

Authors such as Rosalind Williams (2003) and John Heywood (2008) have argued that the engineering profession has lost its identity, and that in the long run engineers will have to face up to a long term convergence between technological and liberal arts education. The prediction is that if engineers do not adopt a hybrid educational model they will be consigned to purely technical work activities. The emergence of new hybrid career professionals requires new engineering educational responses in which student engineers are exposed to the influence of other communities and other disciplines in order to acquire an understanding of how people from other disciplines think. The engineer's identity crisis referred to by Williams (2003) has been re-interpreted by Priyan Dias (2013) as involving three distinct crises to which the discipline and its education provision needs to respond: a crisis of the nature of engineering knowledge, that is a crisis of theory or practice; a crisis of engineering role, that of a scientist or a manager; and a crisis of values underpinning engineering decision making. The changing identity of the engineers and their role in society is in urgent need of clarification to guide educators in their provision of a more comprehensive curriculum and experiential learning formation.

Some authors have argued for a more integrated approach to engineering education, with the objective to make engineering education more reflective of engineering practice, to become more reflective, holistic, and innovative in which "engineering is seen as a socio-technical endeavour that fuses technical disciplines and social science disciplines into a mix that fosters 'a hybrid imagination' (Andrew Jamison et al. 2011). The composite nature of the work of an engineer requires a composite educational model in which a broad set of multidisciplinary skills, knowledge and competencies are developed. There is some evidence that such multidisciplinary approaches are being developed through hybrid undergraduate engineering programs.

Throughout the academic literature and in a number of academic institutions engineering program design is starting to reflect this broader perspective with the expansion of course choice and the development of innovative hybrid programs which combine engineering with non-engineering disciplines. In some instances such as Carnegie Mellon University and Johns Hopkins University in the US, students are offered dual degrees which combine engineering and business in an integrated educational experience which reflects the practice of engineering.

Carnegie Mellon's dual program offers a "new integrated engineering and business program culminating in a Bachelor of Science degree in engineering and a Master's degree in business administration", while Johns Hopkins's dual degree program will offer School of Engineering students a unique opportunity to bridge gaps between the engineering and business fields, prompting the Dean of the Carey Business School to comment that "the nexus between engineering design and business application has never been stronger in today's economy. Breakthroughs and discoveries need to be economically viable to have a lasting impact on the world," (Bernard T. Ferrari 2016, p. 1). The Dean of the Johns Hopkins Engineering School added "Johns Hopkins engineering students are extremely entrepreneurial in the way they approach solving problems. They are eager to turn their innovations into products that can have an impact on people's lives, and the partnership with the Carey School will provide them with the business skills they need to do this" (Ed Schlesinger 2016, p. 1).

Former Harvard President Derek Bok has been quoted as stating that many students graduate college today "without being able to write well enough to satisfy their employers … reason clearly or perform competently in analysing complex, non-technical problems" (Bok quoted in Arum and Roksa 2011, p. 6). While it is not clear whether the exclusion of technical problem solving represents a general absolution for engineering programs and the students and faculty engaged with them, it hints at the larger problem of the disengagement of faculty from active learning by their (engineering) students and whether the heart of this issue rests with the faculty and administrators and not with the students.

17.5 Review of Professional Engineering Programs in Ireland

This section summarizes findings and makes some broad conclusions regarding broadening of the engineering curriculum and the involvement of non-engineering experts, in particular from social sciences, in the education of engineering students. The section concludes with a re-formulation/re-statement of the problem that we are seeking to address.

A high level review of the content of accredited professional engineering programs currently offered by Universities and Institutes of Technology (IoT) in Ireland was carried out by the authors throughout September and October 2017. The objective of the review was to examine the extent and nature of non-core disciplinary modules or elements of modules contained in these programs. The review was limited to readily accessible information, either online or in print format, the extent and level of detail of which varied greatly from one institution to another. As a result some broadening material may have been missed, and some material may have been included that has little broadening effect. But the numerical results provide a reasonable indication of the actual extent of inclusion of broadening material in engineering programs in Ireland, and a qualitative analysis of the program descriptions provides additional evidence of this. It also provides an illustration of the perceived importance of broadening the education of engineers in Ireland within the engineering academic community. It should also be noted that there is anecdotal evidence that individual lecturers often require project work from engineering students within core disciplinary modules with contextual and societal emphasis.

17.5.1 Definition of Broadening Content

Broadening is defined here as modules and content from non-engineering disciplines that are intended to develop a different way of thinking and relating to society and the world. In this sense we take a more inclusive view than humanities alone, but also include the social sciences, the arts and subjects generally related to the commercial, civic or creative domains such as business, management, finance, law, psychology, ethics, citizenship, art, culture, philosophy, spirituality, etc. It does not include content that is part of the traditional core science, mathematics or technology-based content of engineering programs, including related areas such as design, manufacturing, quality, systems engineering, etc. Thus for our purposes, project management is not a broadening subject, whereas other aspects of management can be. Generic and transferable skills such as communication, team-working and critical thinking are deemed to be broadening. Work placements and modules involving service learning/community engagement are deemed to develop generic skills. Semester-long or year-long projects are frequently designed to develop generic as well as technical skills. These were counted as broadening wherever the module title included words such as “integrating”, “team” or “capstone”, or where the module description states that the project contributes to the development of generic skills as a learning objective. Sustainability and environmental impact are deemed to be core engineering concerns and not necessarily broadening per se, although they do give rise to a heightened focus on societal impact. Biological and bioengineering modules and topics are considered core to Biomedical Engineering programs and are therefore not broadening. Electives were not counted as broadening, even when the options included broadening content. However, data were gathered on the number of programs with elective lists that included broadening modules. Optional non-credit bearing modules were ignored. The analysis therefore looks at more than what might be described as “core” business content. This is justified on the basis that the economic, social and cultural aspects of modern life are so interrelated that it is necessary to consider them in the round. Professional and ethical behaviour, generic skills such as critical thinking and communication, and knowledge of the humanities are just as relevant to a business education as to an engineering one. For the purposes of the analysis, broadening content is therefore divided into four categories:

1. Core business content: management, finance, law, marketing, economics etc.
2. Professional and ethical development: including the regulatory environment.
3. Generic Skills: critical thinking, team working, personal effectiveness etc. Work placement and service learning modules were considered significant contributors in this regard.
4. Other broadening non-technical disciplines: arts, humanities, etc.

17.5.2 Programs Included in the Study

There are 94 in-scope professional accredited engineering programs in Ireland, as listed on the Engineers Ireland website (accessed 30 June 2016). Seventy of these are at Level 8 (Honours Bachelor Degree) on the Irish National Framework of Qualifications (NFQ), which is equivalent to Level 6 of the European Quality Framework (EQF), or First Cycle of the Bologna Framework. The remaining 24 are at Level 9 (Master Degree) of the Irish NFQ, equivalent to Level 7 of the EQF or Second Cycle of the Bologna Framework.

Of the 94 in-scope programs, 69 are offered for the 2016/2017 academic year, according to institution websites (accessed September to November 2016). The quality of information available online and in other literature in respect of these programs varies greatly. In some instances, nothing more than a short description is provided. In the majority of cases, a listing of module titles, which provides the

Table 17.2 Number of accredited programs offered in 2016/17

	Number of programs offered			Modules listed	Full syllabus provided
	Level 8	Level 9	Total		
University	29	12	41	39	6
IoT	21	7	28	25	7
Total	50	19	69	64	13

most basic evidence of broadening content, is provided. In a small minority of cases, full details of learning outcomes and syllabus content are accessible. The breakdown of the 69 programs offered in 2016/2017 between levels and sectors, and the types of information available for them are displayed in Table 17.2.

For 5 of the 69 programs, only broad descriptions are provided to the public – module titles are not listed. As noted above, module titles provide the most basic evidence of broadening content, so the 5 programs for which they are not available are excluded from the analysis leaving 64 programs. Syllabus content, along with other relevant information such as Program Learning Outcomes, Module Learning Outcomes etc., are available for only 13 programs. In light of this low number and of the complexity of the syllabus information, the main analysis was conducted on the large proportion of programs – 64 – currently offered for which listings of module titles are available.

Two further programs were excluded from the main analysis and considered separately, as one has "Management" in its title and the other has "Business" in its title. Both were found to be genuinely multi-disciplinary in nature. This brought the number of programs in the analysis in this section down to 62. The two excluded programs are discussed separately below, together with a third multi-disciplinary program.

The number of modules of broadening content that fall into each of the categories identified, again based on their titles, was identified and inferences drawn regarding the extent and type of broadening content. A qualitative analysis of the descriptive material available on all programs was also carried out. The qualitative analysis was informed by syllabus detail where it is available.

17.5.3 Results of the Review of Professional Engineering Programs in Ireland

The number of programs at Level 8 and Level 9 containing 0, 1, 2, 3 or more modules of broadening content across the 4 categories introduced above are separately displayed in Tables 17.3 and 17.4 below.

Table 17.3 Programs at Level 8 containing one or more modules of broadening content

No. of level 8 (Hons Bachelor) programs containing:	Professional and ethical development		Generic skills		Core business topics		Other-humanities etc.	
	No.	%	No.	%	No.	%	No.	%
0 modules in:	16	36%	12	27%	17	38%	45	100%
1 module in:	27	60%	17	38%	24	53%	0	0%
2 modules in:	2	4%	14	31%	4	9%	0	0%
3 modules in:	0	0%	0	0%	0	0%	0	0%
> 3 modules in:	0	0%	2	4%	0	0%	0	0%
Total	45	100%	45	100%	45	100%	45	100%

Table 17.4 Programs at Level 9 containing one or more modules of broadening content

No. of level 9 (Masters) programs containing:	Professional and ethical development		Generic skills		Core business topics		Other-humanities etc.	
	No.	%	No.	%	No.	%	No.	%
0 modules in:	13	76%	11	65%	5	29%	17	100%
1 module in:	4	24%	6	35%	9	53%	0	0%
2 modules in:	0	0%	0	0%	1	6%	0	0%
3 modules in:	0	0%	0	0%	0	0%	0	0%
> 3 modules in:	0	0%	0	0%	2	12%	0	0%
Total	17	100%	17	100%	17	100%	17	100%

17.5.4 Discussion of Findings

The most striking finding is that we could not find a single mandatory module from the arts and humanities included in any of the 62 programs considered. Nine programs include a modern language module as an elective. Two programmes in one university list a module titled "Service Learning & Ethics". No further details are provided.

More than a third of programs at level 8 do not include a single mandatory module with a primary focus on either Professional and Ethical Development or Generic Skills (including work placement modules, or project modules with mention of generic skills). More than a quarter of programs at level 8 do not include a single mandatory module on core business topics. Some small mitigation lies in the availability of broadening modules as electives in the case of 9 of the 45 level 8 programs.

At Level 9, the picture is even more striking. Three quarters of programs at level 9 do not appear to include a single mandatory module on Professional and Ethical Development. Two thirds do not include a single mandatory module on Generic Skills. Some mitigation again lies in the availability of broadening modules as electives (alongside many technical and scientific alternatives) in the case of 9 of the 17 level 9 programs.

Table 17.5 Number of programs with electives that include broadening options

Level	No. of programs
Level 8	9
Level 9	9

Table 17.6 Number of programs in respect of which broadening intent is expressed in the public literature

	Professional and ethical development		Generic skills		Core business topics		Other-humanities etc.	
No. of programs	No.	%	No.	%	No.	%	No.	%
Level 8	2	4%	11	24%	8	18%	0	0%
Level 9	2	12%	4	24%	4	24%	0	0%

At either NFQ level 8 or 9, the number of programs having 2 or more mandatory broadening modules in any of the 4 categories is tiny, with the exception of generic skills at level 8 (35% of level 8 programs have 2 or more generic skills modules).

As previously stated, broadening content that is not reflected in module titles may be contained in core engineering modules. There may be development of generic skills or business knowledge in seemingly exclusively technical projects, for example. A review of the overall program descriptions, however, supports the evidence from the module titles that broadening content is thin. Tables 17.5 and 17.6 display the number of programs in respect of which there is any significant mention of intent to broaden beyond technical mastery in program descriptions or objectives in the published literature on the programs online or in print. The numbers are low.

The evidence from this high-level review leads to the conclusion that the academic engineering community in Ireland in general attaches a low priority to the development of a broader perspective in engineering students, beyond the technical and scientific, evidenced by and reflected in a low level of inclusion of broadening content.

17.5.5 Relating the Review of Engineering Programs to the Taxonomy of Engineering Enlightenment

While we must be cautious relating the above findings to the proposed taxonomy of engineering enlightenment, on the basis that the publicly available program information may not be a true reflection of how a program is delivered, nevertheless the findings in relation to the 62 programs in the main study lend themselves to some confident assertions. If we were to consider only content from the humanities for broadening purposes, then the majority of engineering programs in Ireland are at level 1 in the taxonomy; i.e. the programs are designed and delivered to produce

"I-shaped" engineering graduates. This is clear from the absence of arts and humanities content from the programs.

The situation changes to some extent when the social sciences are included. This includes content from the other three categories of Core Business Topics, Generic Skills (considered to be largely developed through experiential learning) and Professional/Ethical Development. Aside from two outliers in Generic Skills at Level 8 and 2 outliers in Core Business Topics at Level 9, no program has more than 2 modules, or approximately 4% of the program content, in any of the broadening categories.

It is reasonable to conclude that engineering program designers in Ireland generally exhibit limited acceptance of "instrumental justification" for the inclusion of broadening content in engineering programs, with the objective of improved communication skills, and that they attach scant importance or relevance to the higher levels of the taxonomy, concerned with locating engineering projects in the broader social context and with critical self-reflection on the meaning of life in a progressively engineered world.

17.6 Review of Accreditation Reports

The goal of this section is to examine evidence from the accreditation of Irish engineering programs in order to assess the opportunities for broadening of the curriculum and whether such broadening is occurring. We explore whether Irish engineering students (within professionally accredited programs) are being equipped for the roles that they will play in society. Is there evidence coming through Accreditation Visits that this is occurring? We also explore the evidence that exists from accreditation reports that engineering program leaders attempt to ensure that their students study engineering within an environment that supports critical reflection on the role of engineers in creating the society and the world we live in.

In general, the engineering curriculum is designed by engineering academics to meet learning outcomes set by accrediting bodies composed of professional engineers (some of whom themselves are engineering academics). The situation is further complicated by the view of both groups that rigorous engineering standards must be demonstrably met (because engineers are educated to work as engineers) and this has led to crowded curricula that act to push out what are seen as non-essential subjects (and by definition this includes non-engineering topics).

Engineers Ireland is the professional body for engineers in Ireland, with over 23,000 members. It has represented the engineering profession since 1835, and both protects and awards registered engineering titles, including the professional title of 'chartered engineer'. Registered titles from Engineers Ireland provide formal recognition of professional competence, including international recognition. Engineers Ireland is also the accrediting body for engineering education standards, and it conducts accreditation reviews against its published engineering accreditation criteria (Engineers Ireland 2014). Engineering education programs undergo scrutiny every

5 years by independent panels established by Engineers Ireland. Engineers Ireland itself is subject to periodic reviews of its processes and criteria by the European Network for Accreditation of Engineering Education, which authorises accreditation and quality assurance agencies to award the EUR-ACE label to accredited engineering degree programmes (www.enaee.eu).

Accreditation has evolved from an 'inputs' model to one of evidence-based program outcomes (POs), and each program must be able to demonstrate that its graduates achieve these outcomes. Accreditation panels are generally experienced, in that members will have undergone training by Engineers Ireland, and may have participated in a number of previous accreditation visits. According to Damien Owens, the Registrar of Engineers Ireland, "we must recognise that this is a peer assessment so the assessment panel is looking to see if what they are assessing is *substantially equivalent* to the programs that they deliver in their own education institutions or if they deliver to the requirements of industry" (Owens 2016b). Assessment panels comprise two academics and an industry practitioner. Panel members are not always engineers, but non-engineers, for example a medical doctor on a Panel reviewing a Medical Device degree, are additional to the Panel rather than substitutional. In addition to a preparation day, the accreditation visit is conducted over 2 days.

Accreditation based on outcomes is relatively new. Previously, engineering programs were accredited based on defined input criteria set by accrediting bodies. These minimum requirements typically included (i) "qualified, forward-looking and competent faculty; (ii) a defined curriculum (based on engineering discipline) that prescribed specific subjects and minimum durations for those subjects; (iii) quality and performance of the students on the program, including intake quality; (iv) critical facilities to support the program, including classroom space, laboratory space, workshop space, library, etc. (Erkmen and Yurtseven 1994). With accreditation based on input criteria, the philosophy was that quality assurance on each of the inputs (such as minimum entry standards, minimum number of hours of study, required assessment, formalized accreditation processes) provided evidence of the quality of the program (which effectively can be translated as 'generally, good ingredients will make a good cake'). Modern engineering accreditation criteria, based on program outcomes, rather than defined input parameters, are intended to provide greater latitude and freedom to engineering program designers, while also focusing on the abilities of the graduates emerging from the program. With accreditation based on outcomes, institutions can be innovative in program design and pedagogy but must be able to provide evidence that graduates meet the POs for their program. These POs can be tailored to institutional goals and the academic environment in which they will be delivered. In Ireland, "the pedagogy and method of delivery of programs is left to the HEIs" (Engineers Ireland 2014, p. 6).

The program outcomes required to satisfy the criteria for professional (chartered) engineer are as follows.

(a) Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.
(b) The ability to identify, formulate, analyse and solve complex engineering problems.

(c) The ability to perform the detailed design of a novel system, component or process using analysis and interpretation of relevant data.
(d) The ability to design and conduct experiments and to apply a range of standard and specialised research (or equivalent) tools and techniques of enquiry.
(e) An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.
(f) The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning.
(g) The ability to communicate effectively on complex engineering activities with the engineering community and with society at large.

17.6.1 Discussion of Evidence from Accreditation Reports

Criteria (a) through (d) represent what can be termed the traditional core strengths of engineering, and can be considered as 'hard criteria' when viewed through a traditional engineering lens. Criteria (e) through (g) underscore the importance of contextual understanding and practice, and these may be considered as 'soft' criteria through the same traditional engineering lens. The criteria clearly support levels two (instrumental), three (enhanced instrumental) and four (intrinsic value) of the Taxonomy of Engineering Enlightenment (see Table 17.1 above). In this respect, the criteria can act as critical mediating factors that can focus the structure and curricula of engineering programs requiring accreditation. Significantly, Engineers Ireland goes further in terms of detail with respect to its criteria. Each criterion contains a description of what the engineering program should be able to demonstrate. For example, under Criterion (e) "graduates should have, *inter alia*: (i) the ability to reflect on social and ethical responsibilities linked to the application of their knowledge and judgements; (ii) knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline; (iii) knowledge and understanding of the health, safety, cultural and legal issues and responsibilities of engineering practice, and the impact of engineering solutions in a societal and environmental context; (iv) knowledge and understanding of the importance of the engineer's role in society and the need for the commitment to highest ethical standards of practice; (v) knowledge, understanding and commitment to the framework of relevant legal requirements governing engineering activities, including personnel, environmental, health, safety and risk issues" (Engineers Ireland 2014, p. 8). Engineering programs providing evidence that their graduates have these abilities can certainly claim Level 4 on the Taxonomy of Engineering Enlightenment: that their program enables critical self-reflection on the meaning of life in a progressively engineered world, and that their graduates can both transform the world and can reflect on what it means for society. In a similar manner, fully satisfying

Criterion (g) provides evidence of Levels 2 and 3 on the Taxonomy of Engineering Enlightenment.

All of the accreditation reports examined by the authors[1] were for programs that had successfully demonstrated evidence to meet the seven criteria (a) through (g). In that respect, many different accreditation panels independently satisfied themselves by examining program and assessment evidence, interviewing current students, graduates and employers that all seven criteria were successfully met. This is an important point to bear in mind with regard to engineering programs in Ireland. It also suggests that the publicly available information describing programs is often insufficient in describing the strengths, often hidden, of a program and that it takes a more forensic accreditation panel to evince these strengths. For example, from the earlier Review of Programs, this example of critical reflection with respect to Criterion (e) would not be evident: "particular noteworthy examples include Professional Engineering & Communications … which examines 'wicked', multi-faceted problems requiring an examination of societal, political, technical, etc. issues to be recognised – assignment requires ethical reasoning to be emphasised." A different report from a different university notes project "work and in-depth discussions with staff assisted the Panel in assessing if this outcome was being met. Concepts such as integrity, environmental awareness and the likely impact of the graduates' work on society is an integral part of a number of modules in all years".

However, it can also be said that the authors found no evidence of systemic attention to a broadening agenda within the accreditation reports. These reports indicate that often the same (few) courses within a program provide all of the evidence of meeting criteria (e) through (g), or that evidence could be found across a number of courses. It was often the case that accreditation panels found evidence in what might be considered arbitrary and non-rigorous forms. For example, on "the multi-disciplinary aspect, the programme benefited from the fact that students came from different backgrounds".

In reviewing all relevant accreditation reports, the authors looked for, but could not find, clear themes reflecting an institute-wide focus across its accredited programs with respect to criteria e, f, and g. In other words, we could not find evidence that any institution or university used these criteria to set itself apart, or differentiate all of its engineering programs – and therefore all of its engineering graduates – as different and unique. Certainly, where engineering programs shared the same broadening course or modules, the benefits extended to more than one engineering program. But this came across as coincidental rather than instrumental. Perhaps the closest to an institutional culture came from one traditional university with strong commonality across the first 2 years of its programs, and continued sharing of modules in later years. This might be considered as an *intra-engineering hybridicity.* As one accreditation report noted, the "fact that students now are exposed to a common

---

[1] With the support of Engineers Ireland, the authors were given restricted access to all accreditation reports on engineering programs in August 2016, as they are not publicly available. We provide some relevant quotations from these reports where they illustrate key points. The authors would like to thank Engineers Ireland for this access.

first semester gives them some insight into how other engineering disciplines work". More commonly, what was found was a clear focus on developing traditional engineering core values and strengths in graduates, for example the "primary aim of the programme is to produce high calibre graduates, who will possess a thorough knowledge of scientific principles and Engineering Practice and an appreciation of the industrial and business environment of the professional engineer". For a different program in a different institution the "primary objective is to educate students to become engineers who will be able to depend on critical reasoning to effectively apply qualitative and quantitative methods of inquiry to real-world problem solving".

Accreditation panels appear sometimes to try to highlight to institutions that elements of a program require attention, while not refusing that accreditation. For example "consideration should be given immediately to securing opportunities for teamwork in multidisciplinary situations". In another case for "future review exercises, the provision of explicit evidence of where these skills are being addressed should be provided". In yet another report: "the course team may have been modest here in preparation of the material available in the base room as there are likely to be many modules throughout the programme where students are required to work as teams". And again for another program: a "further general observation is that in some modules (namely "the engineer as a professional") there is very good evidence in the form of submitted student work. It would have been useful to have more information on what was asked of the students during this module (e.g. coursework spec or marking scheme)". As a final example, an accreditation report recommends that "formal assessment of ethics is conducted in the service modules (non-engineering modules)".

From the accreditation reports it is clear that within some institutions and universities there have been initiatives to broaden the engineering student's education at the program level, rather than by adding broadening, non-engineering courses. The evidence as to whether this is successful is not clear. For example, a program accreditation report for one institution notes: "Table … listed all modules as contributing to [criterion] (e) and so the evidence provided for all modules was examined in detail. It was evident that all staff members have strong ethical principles and high standards of professionalism and that these values are implicitly instilled in the students in the delivery of all modules. However, not all modules were able to provide evidence that this programme outcome was being formally and explicitly assessed".

Finally, in a discussion with the Registrar of Engineers Ireland that focused on criteria e, f and g, the Registrar noted that Accreditation Panels are becoming more experienced at seeking appropriate balance of evidence between the 'hard criteria' and the 'soft criteria' (Owens 2016a). Engineering students do grapple with societal issues, but often at a micro level. Hybrid programs such as *Engineering with Business* stand out with regard to meeting criteria (e) through (g). Other points noted by the Registrar were that a common gap in criteria evidence is that of students working in multidisciplinary teams especially with non-engineers. The best broadening evidence comes from work placement courses, and community learning projects. "Student work placement allows students to experience the application of their engineering studies and this experience benefits their continuing undergraduate studies." (Owens 2016a). Critical thinking skills are generally assessed by interviewing a small number of students. It was noted that students in some engineering programs appear not to have the time for adequate reflection.

Within the United States, the engineering and technology accreditation body is ABET (Accreditation Board for Engineering and Technology). ABET today has a similar approach to accreditation and program outcomes as does Engineers Ireland, or indeed vice versa. In responding to "calls for more well-rounded engineers who would remain competitive internationally, ABET released its Engineering Criteria 2000 accreditation standards" (Flaherty 2015). With these criteria, student outcomes are often referred to colloquially as 'A through K' under Criterion 3. Criterion 3(h) states that for ABET-accredited engineering programs, student outcomes must include "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (ABET 2016). In mid-2016 ABET signalled that it intended to update its criteria "to ensure they match the reality of today's world, while leading us through the 21st century" (Rogers 2015). The existing eleven student outcomes may be reduced, and the explicit outcomes in 3(h) may change. Given the necessity of ABET accreditation as a value statement for engineering schools, the effect of changes in the EC2000 criteria in terms of program structures and content will be significant. Whether those changes continue to set a broadening agenda in line with Mitcham's critique, or whether they will signal a retrenchment to disciplinary and core engineering is an open question at this time.

17.7 Issues Explored with Leaders and Heads of Business Schools

The following commentary is based on a semi-structured survey of 'expert opinion' among Irish business deans and business program leaders within Irish institutions that also have strong engineering programs. The objective was to gain an understanding of the reality of interaction between engineering and business/management departments in terms of engineering program design, curriculum development and course delivery. The commentary is presented as a discourse reflecting the current state and modality of collaboration, together with a view on the factors inhibiting collaboration.

From these discussions with business school deans and business program leaders it is evident that there is wide variation with regard to both the intention and the practice of collaborative design and delivery of engineering programs at undergraduate level across Ireland. In many cases there is or has been an intention for a broadened curriculum to include business/management department courses. However, over time the inclusion of such models has become limited and is best characterized as informal and marginal with business courses that are available but of little interest to engineering students.

Business and management courses, which are seen as 'not a part of the engineering school culture or ethos' impact on their acceptance within engineering departments. Business deans described engineering programs as 'highly prescribed with very little elective choice', which therefore creates curriculum tension if trying to include non-core engineering courses. There is little evidence of formal collaboration in program or course design, or delivery, and where courses are available they tend to be offered via service teaching, as under-utilized electives, or often delivered by internal engineering department staff.

Business deans commented that most institutions express the view that the broadening of the engineering curriculum to include business/management courses is desirable, but perhaps is best delivered at a postgraduate stage, with the undergraduate program focusing on the students' core engineering education. As seen in the previous section, there is little program evidence that this is occurring. At undergraduate level, current practice is characterized by a 'nodding to business content' with little direct involvement of the business department in either the design or delivery of engineering programs. Business and management content in an undergraduate engineering program has a low priority, and also low interest among both students and staff involved in engineering programs. A contributing influence appears to be the development of a strong engineering identity among students at an early stage in their engineering program which seems to adversely affect the students' views of non-engineering courses.

Where business/management courses are available, they are typically offered as student sourced electives, via service teaching or as courses delivered from within the engineering department under a generic heading such as 'professional development'. In general, such courses have a low priority for students, they are 'not taken seriously', they are of 'little interest', and they are not seen as 'difficult or challenging'. Such views can lead to an under-committed student who under-performs in their business/management courses, creating a program difficulty if such courses are deemed as mandatory for progression. The reasons for such views probably reflect a gradual erosion of non-core engineering courses from the curriculum over time. Business deans spoke of curriculum space issues, different vocational cultures; and a noticeable dis-interest among engineering students and staff in non-engineering courses. The result is a 'squeezing out' or 'chiselling out' of non-core engineering courses from the curriculum over time. Programs that at one stage may have been designed to offer a broader curriculum have been subject to a normative effect over time.

Three primary reasons were offered for the current low level of collaboration between engineering and business departments in the design and delivery of engineering programs. In general three key reasons were cited:

1. The low-value perception of business/management among engineering students and perhaps engineering department staff. There is a prevailing view among respondents that engineering students view business and management courses as 'easy options of little interest', which lack credibility and are not taken seriously leading to reduced effort. The resulting lack of engagement and the failure to

place such courses within an engineering context can partly explain the student antipathy which seems to exist.

2. The issue of curriculum space. A recurring and connected theme among respondents is that of curriculum space combined with the value students and staff place on business/management courses. There appears to be a continual tension in including non-core engineering courses within the curriculum. The extensive, intensive, focused and prescribed nature of undergraduate engineering programs, combined with their perception of business/management courses as having lower worth, mitigate against the allocation of adequate curriculum space to deliver business/management content at an appropriate level.
3. The issue of apparently different educational approaches of the two disciplines. The perception of engineering and business/management as coming from two distinct and different cultures is an inhibitor to collaboration. Whether the view is valid or not the influence is evident. Engineering students can be 'disparaging of business/management courses and don't take them seriously'. Among both engineering staff and students there is a question over the perceived credibility of non-engineering courses. The early formation of an engineering identity among students reinforces the perception and may be a contributing influence.

In the opinion of business deans, the broadening of the undergraduate engineering curriculum to include non-core courses and the collaboration between different disciplinary departments has always been seen as a desirable and worthwhile development – in theory. The practice however appears to be more difficult to achieve and particularly to sustain. The importance of communications, teamwork, people management, soft skills to complement the technical skills of the graduate is evident in the number of engineering undergraduate programs with a 'professional development' course within the curriculum. The question however remains as to whether a 'professional development' course is adequate to address the broadening of the curriculum or embedding the required non-core skills. The view was expressed that the 'engineering student's perspective can be quite narrow' and that 'engineering students are technically very focused' due to the prescribed nature of many engineering programs. A broader societal perspective which contextualizes the role of engineering in society could create a sounder educational experience for the engineering undergraduate. The inclusion of business and management skills such as interpersonal skills, communication, entrepreneurial, marketing and financial analysis skills was offered as useful additions to the undergraduate engineering curriculum.

Some respondents felt that the pivotal role of engineering in society required undergraduate students to have a broader educational experience characterized by a social sciences perspective rather than a narrow business and management perspective. Either way, the current and dominant narrow concentrated nature of many engineering programs with their curriculum and students focused on increasingly specialised core courses will not deliver the engineer whose role is to help solve the large problems faced by today's society.

The educational approaches and traditions of engineering and business have sometimes been characterized as opposites, the former dealing with technical, evidential and procedural based knowledge while the latter more involved with intangible, ill-defined, concept based knowledge. In reality, this dichotomy was never truly real, particularly for engineers who progressed from technical roles to operational and then strategic roles. Business and management courses with their use of broad problem-solving case studies, problem-based learning approaches and dealing with ambiguity could offer additional skill sets of use to the graduate engineer. In reality, such skills reflect the actual practice of the professional engineer, engaging in critical thinking, being a reflective practitioner and seeking workable solutions to ambiguous problems.

The inclusion of non-core courses in undergraduate engineering programs will require an acceptance by both students and staff of the legitimacy of such courses as well as the creation of adequate curriculum space. In part it will require a structural change in the design of engineering programs, but perhaps the biggest challenge will be the change in mind-set on the part of engineering students and engineering staff.

The existence of successful engineering based undergraduate programs which include innovation and enterprise in other jurisdictions such as the US should give cause for optimism and point to the development of a broader more societally based education model for undergraduate engineers.

Apart from the questions of curriculum space, the perceived value of non-core courses and the perceived 'cultural' differences, the status of the 'engineer identity' is perhaps the greatest inhibitor to the broadening of the engineering curriculum to include non-core engineering courses.

17.8 Hybrid Programs

Three programs with significant broadening content are outlined in the table below. The ME in Engineering with Business and the BAI in Engineering with Management are the two programs that were excluded from the earlier engineering program review, on the basis that their titles set them apart from the remainder of the engineering programs reviewed. The BSc in Product Design is a joint venture between three colleges within DIT: Engineering & Built Environment, Business, and Arts and Tourism, and is discussed in greater detail below. It is clear from the modules listed that the programs in Table 17.7 are true hybrids of engineering and business, each clearly designed with broadening in mind. Hybrid programs are discussed in more detail below.

The accreditation report for the hybrid *Engineering with Management* program speaks highly of the program. The broadening evident in the program content matches the findings detailed in the accreditation report, which include *inter alia* that "students graduate with a very broad base of knowledge covering engineering subjects, ethics, financial and business skills; engineering and management is a very strong combination; … there is strong evidence of the building of interdisciplinary

Table 17.7 Examples of multi-disciplinary programs

Program name	BSc product design	ME engineering with business	BAI engineering with management
Institution	Dublin Institute of Technology (DIT)	University College Dublin (UCD)	Trinity College Dublin (TCD)
Accreditation	Institution of engineering designers	Engineers Ireland	Engineers Ireland
Broadening Courses	Economics;	Accounting for non-business students;	20% of courses comprise management subjects such as marketing, finance, quality systems, supply chain management, and human resources management
	Marketing;	Entrepreneurship in action;	
	Communications;	Management & org behaviour;	
	Management and strategy;	Energy economics and policy;	
	Marketing research;	Professional engineering (Finance);	
	Enterprise development/business process management;	Professional engineering (Management);	
	New product introduction;	Engineering with business thesis;	
	Legal aspects of product design;	Operations management;	
	Marketing case studies;	Professional work placement;	
	Professional practice	Business information systems management;	
		Marketing management;	

skills within the programme especially with the Business School" (Engineers Ireland Accreditation Reports 2016).

For the hybrid *Engineering with Business* programme, the criteria e, f and g are all covered through multiple modules and via the work placement activity. Among the list of features and strengths of this hybrid program, the following are noted from among others: "the Engineering with Business Masters program is unique in the country and staff and management must be commended for identifying this opportunity to support Irish industry. It was obvious from the visit that the programs and staff were actively supported by senior management in the College and there was high morale among the Engineering Teams delivering the programs, showing a caring ethos for students and overall welfare of the University" (ibid). Here again, the very strong accreditation report regrading criteria e, f and g, matches the broadening evidence identified through the program review.

17.8.1 Detailed Discussion of One Hybrid Program: DIT Product Design

This section discusses one hybrid program that appears to be an outlier with regard to success in broadening an engineering curriculum. DIT offers a 4-year multidisciplinary program in product design. While not accredited by Engineers Ireland, it is accredited by the UK Institution of Engineering Designers (IED). As such, it is not strictly in scope for this study. However, as an imaginative amalgam of core engineering content with substantial creative and business content, it is arguably one of the very few programs in Ireland conceived and designed ab initio as a collaborative program, and managed in a truly multidisciplinary manner with engineering, arts and business disciplines acting and interacting as equals, rather than on a 'core' and 'non-core' basis. This program is used as a comparator with general engineering programs in terms of student perceptions in the section on the Irish Survey of Student Engagement, discussed below. It has been running in DIT for just over 10 years.

Within this program, students study how the creative aspect of design integrates with the analysis and manufacturing process. Bringing a concept to market is covered in courses such as Economics, Marketing and Legal Aspects of Product Design, New Product Introduction and Business Process Management. Students are expected to enter national and international design competitions. The 3rd year project "consists of an open-ended design brief to which … students are expected to apply design, engineering and business skills in order to produce a viable and marketable product" to a professional and industrial standard (O'Kane and McDonnell 2011). Lecturers collaborate to ensure that both the design and business aspects of the project being developed are considered in tandem. Students are given instruction in design, business and engineering to enable them to create a "marketable product which displays creative design flair, an understanding of technical issues and real business potential" (Colm O'Kane et al. 2014).

Another feature of the program, borne out of both compromise and necessity, is that students spend part of their week at the DIT Engineering campus, at the DIT Business campus, and at the new DIT Arts campus. "Of particular concern to the lecturing team was the aim of encouraging deeper learning through use of group work rather than previous approaches, which have tended to focus on retention and reproduction of material delivered in a traditional lecture setting." (O'Kane and McDonnell 2011. p. 1) A novel approach developed by lecturers in this setting was the use of Computer Supported Collaborative Learning tools to overcome the challenges presented by co-supervising from different location. Resources developed by lecturers to aid others in developing these tools have been added to the national digital learning repository (Colm O'Kane, 2012).

To examine the degree of success of this program in meeting its aims, we turn to a recently introduced national student survey. In 2015 Ireland implemented a national higher education student survey. Students from the 1st year and from the final year of all higher education programs are surveyed. Nine engagement indicators (EIs) are measured including the following three for our purposes: *Reflective and Integrative Learning, Quantitative Reasoning* and *Collaborative Learning.* Each EI is assessed by a number of questions. The 2015 response rates were adequate for statistical analysis with a high confidence level in the results. Each Engagement Indicator was scored on a 60-point scale. A score of zero meant that a student responded at the bottom of the scale for every question in that Engagement Indicator, while a score of 60 indicates a student response at the top for every question. The results in the tables below show the resulting mean scores for all relevant students in each category. When considering these results it must be borne in mind that these are based on how freshmen and final year students interpret their learning in response to the questions.

Table 17.8 presents results for the DIT Product Design program, for all relevant DIT engineering programs, for all DIT programs (this includes engineering, business, applied arts, sciences, etc.), for all relevant engineering programs nationally, and finally all higher education programs in Ireland. The results indicate, that for these indicators, DIT Product Design students report higher levels of reflective and integrative learning and collaborative learning. For quantitative reasoning, it is also quite surprising that DIT Product Design students report scores that are marginally above the average of all DIT engineering programs, and on a par with all engineering programs nationally. Clearly these students do not believe that their program is not analytic. The two benchmark columns of “All DIT programs” and “All Irish programs” include all programs in the Humanities, Social Sciences, the physical sciences and engineering. Taken in this context, the results for the hybrid DIT Product Design program are remarkable.

Table 17.9 provides survey data in response to 5 questions (out of the total of 66 questions) from the survey. Each student, in response to each question, could answer Never (=0), Sometimes (=20), Often (=40), Very Often (=60). The table values are the averaged values. The results for DIT Product Design are again remarkable. For each of the first four survey questions, the self-reporting students indicate scores significantly above their DIT engineering student peers, all DIT students and all Irish students. DIT Product Design students connect their learning to societal issues, they self-reflect, they seek to understand other’s perspectives, and they solve complex real-world problems.

Table 17.8 Mean scores for three engagement indicators

Engagement index	DIT product design	All DIT engineering programs	All DIT programs	All Irish engineering programs	All Irish programs
Reflective and integrative learning	34	27.8	28.9	27.6	30.7
Quantitative reasoning	22.9	22	18.9	23.6	18.8
Collaborative learning	37.2	32.9	31.4	33	30.5

Table 17.9 Survey responses to selected questions

Selected student survey questions	DIT product design	DIT: Engineering	DIT: all disciplines	National: all disciplines
Connected your learning to problems or issues in society	33.3	22.7	24.9	28.0
Examined the strengths and weaknesses of your own views on a topic or issue	34.0	27.8	28.3	30.0
Tried to better understand someone else's views by imagining how an issue looks from their perspective	37.3	28.6	29.4	32.0
Solving complex real-world problems – (How much has your experience at this institution contributed to your knowledge, skills and personal development in the following areas?)	42.2	34.7	29.2	30.0
Being an informed and active citizen (societal/political/community) – How much has your experience at this institution contributed to your knowledge, skills and personal development in the following areas...	27.4	22.2	22.4	36.0

The final question is also illuminating in that they self-report significantly below all Irish students with regard to being an informed and active citizen, but still 5 percentage points above all DIT engineering and indeed all DIT students. With these results, the DIT Product Design students score Level 4 on the Mitcham Enlightenment Framework.

17.9 Conclusion and Recommendations

This chapter has examined Carl Mitcham's claim that the greatest challenge facing engineers "is cultivating deeper and more critical thinking among engineers, and non-engineers alike, about the ways that engineering is transforming how and why we live" (Mitcham 2014).

Engineers Ireland accreditation criteria provide the means to address Carl Mitcham's concerns, including enabling critical self-reflection on the meaning of life in a progressively engineered world especially through criterion (e) and what is expected of engineering graduates. Engineers Ireland has developed a robust set of accreditation criteria particularly for the 'softer criteria' of ethical and societal implications, critical thinking, multi-disciplinarity, and communications. However the publicly available information describing engineering programs is often lacking in describing the strengths of a program, and it takes a more forensic accreditation panel to evince these strengths. Perhaps both the criteria are too new for programs to have fully evolved, and the accreditation panels not sufficiently experienced, broadly constituted and trained, but the consistent evaluation of program evidence is lacking. In this regard, Engineers Ireland might consider providing better guidance with a view to ensuring more consistency in how Accreditation Panels assess criteria e, f and g.

It may also be the case that the link between the academic engineers teaching on the engineering programs and the professional engineers on accrediting bodies is too close, characterized perhaps as too restricted a gene pool. This link has been commented on in the wider sense of its implications for the university by Robert Paul Wolff in his 1969 work on *The Ideal of the University* (Wolff 1969) in which he argues that the ideal university should not be a training camp for the professions. It has also been argued that accrediting bodies should not be comprised solely of engineers but that they should also contain non-engineering lay people (Grimson and Murphy 2013).

There are a number of ways to address the concerns raised by Carl Mitcham, which set the context for this chapter. The first is to reject Mitcham and to 'let engineers be engineers' and consequently society at large should mediate the technology the engineers produce. In this regard, supporting a vibrant liberal arts counterbalance within higher education, and indeed society, is essential. Such an approach would reinforce rather than challenge current orthodoxy, leading to a continued 'two culture' society. It can also be observed that perhaps Mitcham has connected the individual engineer's responsibility with the collective responsibility of engineering to society. While the codes of ethics of professional bodies provide the rule book by which individual engineers should practise their profession, it is through the consistent application of the accreditation criteria by which collectively the profession itself can best be re-oriented. "Ethics curricula have previously focused on microethics, the responsibilities of engineers and other researchers to each other and to the profession, rather than macroethics, the responsibility to society at large" (David Guston quoted in Kaplan-Leiserson 2015, p. 23).

A second way to address Mitcham's concerns would be to leverage the social sciences in instrumental support of engineers. For example, Zakaria, while noting that "a liberal education is out of favour", has stoutly defended the values and strengths of a liberal arts education, including how to write clearly, how to express oneself convincingly, and how to think analytically (Fareed Zakaria 2015, p. 15).

Finally, a third way to address Mitcham's concerns is to increase the number of 'non-core' engineering courses within the engineering curriculum, i.e., to increase the hybridity of curricula. The degree to which undergraduate engineering programs can include more and more non-core courses in their curriculum and still retain engineering status is an important consideration influencing greater collaboration. Generally, engineering program leaders talk about the challenging need to meet accreditation requirements. Yet the Engineers Ireland accreditation criteria e, f and g call for a diligent approach to broadening the curriculum. In addition, the programs that appear to most clearly provide evidence of that broadening are the hybrid programs of engineering with business, engineering with management, and product design. Whether there can and should be a limit to the degree of hybridization in engineering degree programs remains an open question in Ireland.

The issue of hybrid engineering programs leads inevitably to the concept of hyphenated engineers, for example entrepreneurial engineers, business engineers, etc. It could be argued that this is in fact a continued evolution of engineering education and the initial hyphenated engineers were the mechanical engineers, the electrical engineers, etc. The formation of such hybrid engineers is problematic in two ways in that. First, non-engineers cannot create engineers. Second, engineers have a professional identity which is normative and generally acts to maintain the *status quo* for what defines an engineer and how engineers are educated. As Meijknecht and Drongelen have said, "like the medical, the educational and the juridical professions, engineers constitute a tribe, with its own traditional set of values that are transmitted to the new members in a symbolic way during their initiation. Studying is a kind of initiation" (2004, p. 448). The notion of *tribe* also reinforces the challenges discussed surrounding core versus non-core, or engineering versus non-engineering within the education of the engineer. To engineers, the fear of diluting the core identity of the engineer is a concern, and it acts as an inhibitor to the acceptance of a broader educational experience for engineers. Within the tribe what is not core, what is not engineering, has lower value, is of lesser importance. Mitcham also refers to *them* and *us* when he says that "Engineers, like all of us, should be able to think about what it means to be human" (Mitcham 2014). Broad accreditation criteria, such as Engineers Ireland's e, f, and g criteria, can act as powerful policy instruments to ameliorate the perception of *them versus us.*

Another important issue, although outside the scope of this chapter, is the system into which the engineer is placed after graduation – a system which has evolved to focus on unrestrained growth. Perhaps the one argument guaranteed to most disgruntle those who see unrestrained technological development as the source of societal and global problems, is that engineers are necessary and essential actors in humankind's search for a sustainable future. The world today, through the relentless development and application of technology, is currently consuming far more resources than is sustainable into the future. Before we argue over who gets to decide on what a better society is, we need to ensure that we will have a society to argue over. In other words, for those who would hold the engineer responsible for creating the problem, the fact is that the problem cannot be solved without the engineer; or perhaps more accurately, that any solution without the involvement of the engineer would be sub-optimal.

17.9.1 Recommendations

The recommendations made here are on the basis that broadening the engineering curriculum is beneficial and necessary. As has been noted, the accreditation criteria used by Engineers Ireland are adequate for the purpose of ensuring that professional engineering students receive an education that provides them with the broad foundation necessary to maximize their contribution to society. These criteria are reviewed on a regular basis. In terms of the fundamental concern raised by Mitcham, and the overview of evidence presented in this chapter, a more fundamental review might now be timely. Such a review should focus not on the technical strengths of engineering programs, which we accept as good to excellent, but rather on the nature of engineering education in a rapidly changing and increasingly complex environment. Since professional body accreditation will continue to act as a normative agent in shaping engineering education, it is important that such bodies strive to remain "ahead of the curve" for how both society and industry need engineers who can think and reflect on the meaning of their work. Such a review could commence with a philosophical debate, including engineers and non-engineers, on the role of engineering in a progressively engineered world, and the consequential education of the engineer.

This chapter has highlighted that, notwithstanding the presence of broadening criteria, systemic evidence of meeting these criteria through structured programmes appears to be absent. While this is not intrinsically negative, it appears that meeting the broadening criteria too often relies on how courses are delivered and perhaps a loose interpretation of evidence on the part of the accreditation panel. To address this, accreditation panels should contain at least one non-engineer, perhaps with the role and perspective to 'speak for society'.

The most fundamental recommendation is made for the engineering educational institutions themselves. Engineering, as a collection of academic disciplines, is not alone in displaying resistance to the inclusion of non-core subjects into the curriculum, and the development of multidisciplinary and interdisciplinary approaches to higher education, but it is arguably more disadvantaged as a result. Elements of the technocracy that Veblen envisaged have materialized, but generally engineers have less influence and control than Veblen conceived. An argument might now be made that the narrow technical focus of engineering programs and educational environments contributes to the general diminution in the role of the engineer from an expert astride the wheel to a cog on it. Engineering education institutions should therefore engage in self-reflection about their education processes. Group think, by way of only consulting engineers, should be avoided. The educational philosophy, curriculum framework, and the pedagogical model for each engineering programme should be developed, before any programmatic content is agreed. Diversity of voices should be admitted into the design and delivery of engineering programs. Each engineering program must ask each engineering student to reflect on what it means to be an engineer, and why that student wants to be an engineer.

Finally, the authors accept and acknowledge that the evidence upon which this chapter makes its arguments is neither comprehensive nor rigorous. But the evidence uncovered supports the arguments made. Ireland is a small, open, globalized economy with a relatively new, strong and diverse engineering base. Given the points outlined in this chapter, Ireland itself could be a good test case for engineering education. This could begin with a more comprehensive examination of the questions addressed in this chapter, in particular with regard to the apparent strengths of hybrid programs. Different engineering education institutions could seek to establish distinct and differentiated engineering experiential learning, which can in turn be studied, and all of which will result in a greater diversity of engineering graduates to better serve society.

References

ABET, Inc. (2016). http://www.abet.org. Accessed 9 Jan 2017.

Arum, R., & Roksa, J. (2011). *Academically adrift–limited learning on college campuses*. Chicago: University of Chicago Press.

Christensen, S. H. (2015). *Issues in Science and Technology*.

Dias, P. (2013). The Engineer's identity crisis: Homo faber or homo sapiens? chapter 11. In *Philosophy and Engineering: Reflections on practice, principles and process*. New York: Springer Science+Business Media.

Duderstadt, J. J. (2008). Engineering for a changing World: A roadmap to the future of American engineering practice, research and education. In D. Grasso & M. Brown Burkins (Eds.), *Engineering education for the 21st century: A holistic approach to meet complex challenges*. New York: Springer Science+Business Media.

Engineers Ireland. (2014). *Accreditation Criteria*. Retrieved 29 Dec 2016.

Erkmen, I., & Yurtseven H.O. (1994). Accreditation issues in electrical engineering curriculum: A comparative case study. IEEE.

Ferrari, B. T. (2016). *Carey, whiting launch business, Engineering dual degree*. http://careybusiness.carey.jhu.edu/blog/2016/11/07/careywhiting-launch-business-engineering-dual-degree/

Flaherty, C. (2015). Watered-down Gen Ed for Engineers? *Inside Higher Ed*. 26 June 2015.

Goold, E. (2015). Professional formation of engineers: Enhancing the first year student experience. European Society for Engineering Education Annual Conference, Orléans, 2015.

Grimson, W., Murphy, M., Christensen, S. H., Erno-Kjolhede, E. (2008). Philosophy matters in engineering studies. The 38th. ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, New York. October 22–25, 2008.

Grimson, W., & Murphy, M. (2013). Making the case for the inclusion of lay persons on Engineering accreditation panels: A role for an Engineering Hippocratic Oath? chapter 15. In *Philosophy and Engineering: Reflections on practice, principles and process*. New York: Springer Science+Business Media.

Hansen, M. (2010). IDEO CEO Tim Brown: T-shaped stars: The backbone of IDEO's collaborative culture. Retrieved from http://chiefexecutive.net

Heywood, J. (2008). Philosophy and engineering education. A review of certain developments in the field. Frontiers in Education Conference 2008. FIE 2008. 38th Annual, pp. S4H-7-S4H-12, ISSN 0190–5848.

Jamison, A., Christensen, S. H., Botin, L. (2011). A hybrid imagination: Science and technology in cultural perspective. Synthesis lectures on engineers, technology, and society. Morgan & Claypool Publishers: Golden Colorado, 6, 2, 1–180.

Kaplan-Leiserson, E. (2015). Designing the future – do PEs have an ethical responsibility to think ahead to help prevent harmful effects of technology? NSPE Magazine for Professional Engineers, May 2015.

Meijknecht, T., & van Drongelen, H. (2004). How is the spirituality of engineering taught or conveyed? *International Journal of Engineering Education, 20*(3), 447–451.

Mitcham, C. (2014). The true grand challenge for engineering: Self-knowledge. *Issues in Science & Technology*, Fall Issue, 18–22.

O'Kane, C. (2012). Leveraging collaborative learning technology to support group learning in engineering education, NDLR Fest 2012: 6th Annual Irish Showcase for Digital Learning Resources Dublin, May.

O'Kane, C., McDonnell, J. (2011). Use of collaborative learning technology to support cross-faculty group learning. Proceedings of EDULEARN11: International Conference on Education and New Learning Technologies, Barcelona, 4th – 6th July, 2011, pp. 925–933.

O'Kane, C., McDonnell, J., Mooney, E., Tierney, D. (2014). Designing enterprise: Merging technical and business considerations in new product development. ICSB World Congress on Entrepreneurship, June.

Owens, D. (2016a). Notes from authors' meeting with registrar of Engineers Ireland, 5 Aug 2016.

Owens, D. (2016b). Outcome-based education and Engineering education accreditation. China Association of Science and Technology (CAST) innovation and integration Engineering education accreditation international symposium, Beijing. April 2016.

Rogers, J. (2015). Jamie Rogers, ABET president, explains the reasoning behind proposed changes to criteria 3 and 5. ABET news brief, 2 September 2015.

Schlesinger, E. (2016). Carey, whiting launch business, engineering dual degree, http://careybusiness.carey.jhu.edu/blog/2016/11/07/carey-whitinglaunch-business-engineering-dual-degree/.

Trevelyan, J. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175–195 First published on 13 October 2010.

Trevelyan, J. (2013). In B. Williams, J. Figueiredo, & J. Trevelyan (Eds.), *Towards a theoretical framework for engineering practice, engineering practice in a global context: Understanding the technical and the social* (pp. 33–60). Leiden: CRC Press.

Trevelyan, J. (2014). *The making of an expert engineer*. London: CRC Press.

Veblen, T. (1921). *The engineers and the price system*. Kitchener: Batoche Books.

Williams, R. (2003). Education for the profession formerly known as engineering. *The Chronicle of Higher Education*. Issue January 24th.

Wolff, R. P. (1969). *The ideal of the university*. Oxfordshire: Taylor & Francis, Ltd.

Wulf, W. A., & Fisher, G. M. C. (2002). A makeover for engineering education. *Issues in Science and Technology, 18*(3), 35–39.

Zakaria, F. (2015). *In defense of a liberal education*. New York: W.W. Norton & Company.

Mike Murphy PhD and MEng degrees in electrical engineering from Stevens Institute of Technology. Prior to that he graduated with an Honours Diploma in Electrical Engineering from Dublin Institute of Technology, and BSc (Eng) Honours Degree from Trinity College Dublin. He is a Fellow of Engineers Ireland and a Member of the Institute of Electrical and Electronics Engineers. He is President of the European Society for Engineering Education (SEFI) and is past Chair of the European Engineering Deans Council. He commenced his industry career with AT&T Bell Labs in New Jersey, and later worked with Bell Communications Research before returning to the academy in 2002, when he joined Dublin Institute of Technology as Director and Dean of the Faculty of Engineering. In 2009 he accepted responsibility for the newly formed College of Engineering & Built Environment at Dublin Institute of Technology, which he led as Dean until January 2014. Mike is currently the Academic Registrar at DIT and is Director of Academic Affairs, Digital Campus & Learning Transformation.

Pat O'Donnell He joined the TU4Dublin Team, which was set up to enable Dublin Institute of Technology, Institute of Technology Blanchardstown and Institute of Technology Tallaght Dublin (ITTD) to join together and seek designation as a Technological University (the TU4Dublin project), in February 2014. He was a co-leader in phase 1 of two of nine Foundation Themes, "Dublin's Globally Engaged University" and "The Enterprising University", designed to transform the new institution and to ensure it meets the criteria laid down for designation as a TU. He is currently leading a number of implementation and mainstreaming programmes. He is a Chartered Electrical Engineer, with 12 years' experience of design and project-management on large infrastructural projects. He also holds an MA in Multimedia Systems and a Higher Diploma from Kings Inns in Legal Translation. He was a founding academic member of staff of the Institute of Technology Tallaght Dublin (ITTD) in 1992. During his initial 10 years as an academic, he developed a strong track record in applied research and industry engagement at a time of rapid growth of knowledge-based industry in Ireland. As Industrial Liaison Manager of ITTD from 2002 to 2011, he led strong growth in research activity, the development of the highly successful Synergy/M50 Enterprise Platform Programme and ultimately the development of the Synergy Business Incubation Centre on campus. He returned to an academic role in ITTD as Head of the School of Engineering in March 2011.

John Jameson BSc (Hons) Mgmt, MBS (International Business), Advanced Diploma in Marketing Techniques, PG Diploma in Research Methodology, PG Diploma in Advanced Research Techniques. He is Head of School in the College of Business, and Director of Engagement in the College of Business at Dublin Institute of Technology; he is also Director of the Arthur Ryan Retail Centre (ARRC) and has over 25 years of C-Level management consulting experience in organisational and executive development in multi-national organisations across a number of industry sectors. Through the ARRC, John has led a range of industry engagement and outreach activities, including research projects involving the development of a socio-economic-cultural model of retail within the Irish context; and a longitudinal study of the changing retail landscape of Irish villages, towns and cities. Most recently John's research interests reflect his doctoral research in the area of Graduate Employability and Professional Reflective Practice particularly in respect of graduate internship as an effective development process for graduates entering the business/management domain. John has been actively involved in a number of European projects including EUREMA, the European Competence Center for Vocational Training (ECCVT) and BIOINNO, a Knowledge Alliance project facilitating inter-sectoral mobility between Industry and Academia. He has been a visiting professor at Pharos University in Egypt since 2010.

Chapter 18
To What Ends: Engineering, Technology, and Business Program Perspectives as to Their Key Purposes with Regard to the Society Housing Them

Michael Dyrenfurth and Gary Bertoline

Abstract The purposes of higher education have been debated ever since tertiary education emerged. Not surprisingly these discussions have also addressed the purposes of Business, Engineering and Technology (BE&T) programs in higher education. Furthermore, given the obvious and frequently threatening challenges of contemporary society, there have been multiple voices calling for attention to the social welfare of all of the world citizens and their quality of life. The intersection of these concerns with the pragmatic nature of BE&T programs has engendered some calls for change. The authors of this chapter examine the extent to which the actual undergraduate plans of study reflect any evidence of attention to ethics, corporate social responsibility, and conscious capitalism – collectively referred to as *larger outcomes*. In addition to an analysis of the plans of study of BET programs, the authors interviewed thought leaders, reviewed literature, and conducted two case studies/vignettes of exemplary programs to see what the future might hold. The chapter ends with a provocative set of conclusions, recommendations for practice and for further research.

Keywords Engineering · Engineering Technology · Program transformation · Program outcomes · Baccalaureate · Conscious capitalism · Ethics · Corporate social responsibility

---

M. Dyrenfurth (✉)
Technology Leadership and Innovation Department, Purdue Polytechnic Institute, Purdue University, West Lafayette, IN, USA
e-mail: mdyrenfu@purdue.edu

G. Bertoline
Purdue Polytechnic Institute, Purdue University, West Lafayette, IN, USA
e-mail: bertoline@purdue.edu

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_18

18.1 Introduction

A major proportion of American higher education effort is devoted to developing individuals with the capabilities needed by business and industry. At the undergraduate level, 4-year baccalaureate programs, which are the focus of this chapter, serve as a primary vehicle providing the entry-level professional work force for business and industry. Because these graduates constitute a major input to business and industry it is important that their programs meet the current and future needs of such employers. We refer to these employer-demanded skills and occupational competencies as *pragmatic capabilities*. However, the programs must also meet the needs of the individuals who graduate from such programs as well as the needs of the society housing the individuals and the enterprises that hire them. There are a multitude of such needs, and we refer to these as *larger outcomes*. The focus of this chapter will be on business and industry needs for entry level professionals.

A large proportion of newly employed professionals in business and industry come from undergraduate business, engineering and technology programs – a fact not surprising given the technology- and economically-dominated world these new graduates are entering. These new professionals are encountering an increasingly interconnected work world that is facing escalating challenges (Schwab 2016) of competitiveness, sustainability, equity, resource constraints, and attendant policy tensions. Clearly business and industry in such an environment can turn to short-term expedient solutions that unfortunately lead to more serious issues later. In fact, much of the attention to short term gains has been blamed for shortsightedness and capitalism run "amok". Fortunately, we have also observed a small but growing attention to sustainability, corporate social responsibility and conscious capitalism (Mackey and Sisodia 2014), also referred to as the "triple bottom line" (The Economist 2009). According to these authors, and simply stated, conscious capitalism, refers to enterprises that consider their impact on all constituencies – not just their shareholders/owners. Sustaining these desirable directions however seems to call for a new type of young professional, i.e., one who, in addition to his/her area of expertise, is also equipped with and willing to exercise thoughtful reflection about whether a given course of action is appropriate. Of course, such professionals must also come equipped with twenty-first century skills such as systems understanding and broad-scale technological insight.

Given the goal of the volume housing this chapter, the authors' intent is to primarily focus on engineering and technology programs although business programs will also receive some attention. More specifically, as an outgrowth of the continuing attention to examining the purposes of education and the university (Abowitz 2008; Christensen and Eyring 2011; Delbanco 2014; Pellegrino and Hilton 2012), we investigate how such programs go beyond addressing merely the basic pragmatic competence of such graduates. How do these programs cause their graduates to consider the knowledges, skills and attitudes necessary to cogently address the larger issues of what is appropriate for business and industry to do, i.e., what considerations beyond technological capabilities and profitability should be woven into the day-to-day conduct of their career lives? How do engineering and technology programs, and business programs, develop such considerations and the social responsibility of their students? Where do students address the requirements for responsible citizenship? Or where and how do students encounter the intersections of ethics with corporate motives for profit? How do engineering, technology, and business majors confront design issues as to what kinds of products and services are appropriate given the grand challenges facing society? What are the social responsibilities of managers, engineers and technologists?

Where and how do engineers, managers, technologists and applied scientists in development, engage in reflective critique of assumptions related to business, economic and technocratic thinking. Conversely, where and how do managers and business leaders confront the intersections between engineering and technological thinking, ethics, and values?

These questions seem a logical outgrowth of precursor discussions dealing with the social responsibility of business and industry and more recently the morphing of such perspectives into a more contemporary vision under the banner of conscious capitalism. The authors define conscious capitalism as an approach to doing business/operating in either for profit or other sectors, to create simultaneous values that benefit all involved, directly and indirectly. Such benefit/value requires collaborative consideration and enhancement of “financial, intellectual, physical, ecological, social, cultural, emotional, ethical, and even spiritual consciousness” (Mackey and Sisodia 2014, p. 32).

What results have been engendered by the ongoing reexamination of the roles of universities (Rego 2014; Saichie and Morphew 2014) in the years since the turn of the millennium? The authors’ overview of recent scholarship in this direction revealed a predominance of pragmatic foci – particularly for articles authored by US-based scholars. European authors in contrast seem somewhat more attuned to such concerns despite which however their predominant baccalaureate program emphasis is also on pragmatic competence and not in the direction of more social consciousness and value examination. We decided to test our assessment by reviewing the actual practice in baccalaureate programs in business, engineering and technology of a selected but diverse sample of American universities. Additionally, we supplemented this data with discussions and qualitative interviews of responsible program administrators as well as a targeted review of some key literature. Finally, we augmented our work with a set of case studies of exemplary program initiatives in order to enlighten our conclusions and recommendations section.

This chapter is structured to first describe the spectrum of programs serving business and industry and then characterize them in terms of their stated purposes. Subsequently the authors examine where these programs help students realize larger overarching purposes and value development. While we highlight several field-specific programs to such ends, we leave our authoring task with the uncomfortable feeling that, in the USA anyway, such innovative initiatives only represent a small proportion of our enterprise. Fueled by this sense, we end the chapter with what hopefully constitutes a provocative set of recommendations and suggestions for further research.

18.2 The Spectrum of Programs Serving Business and Industry

In the United States, as in most advanced nations, a complex spectrum of programs serve business and industry. The higher education sector includes technical institutes, both private and public, community colleges, universities, also both public and private, and proprietary enterprises. To make this chapter manageable attention is limited to 4-year post-secondary institutions, most of which carry the word university in their name, although others employ the word college, school or institute. For the purposes of this chapter such differences in name are irrelevant. Figure 18.1 locates this focus in context.

For the USA, the NCES *Digest of Education Statistics: 2013* Chap. 3 reports:

> During the 2013–14 academic year, 4,724 accredited institutions offered degrees at the associate's degree level or above (table 317.10). These included 1,625 public institutions, 1,675 private nonprofit institutions, and 1,424 private for-profit institutions. Of the 4,724 institutions, 3,039 were 4-year institutions that awarded degrees at the bachelor's or higher level (https://nces. ed.gov/programs/digest/d14/ch_3.asp).

Of this complex, our chapter deals only with baccalaureate level university programs. Furthermore, of the array of programs encompassed by this segment, we focused specifically on business/management, engineering, and technology programs because of their importance in supplying new entry level professionals to the economic engines of our society.

According to the National Center for Education Statistics (NCES 2013, 2016a) American universities reported that "Of the 1,840,000 bachelor's degrees conferred in 2012–13, the greatest numbers of degrees were conferred in the fields of business (361,000)...". The same source showed 81,382 engineering baccalaureates awarded and 17,158 in the engineering technologies along with the authors' estimated 15,000

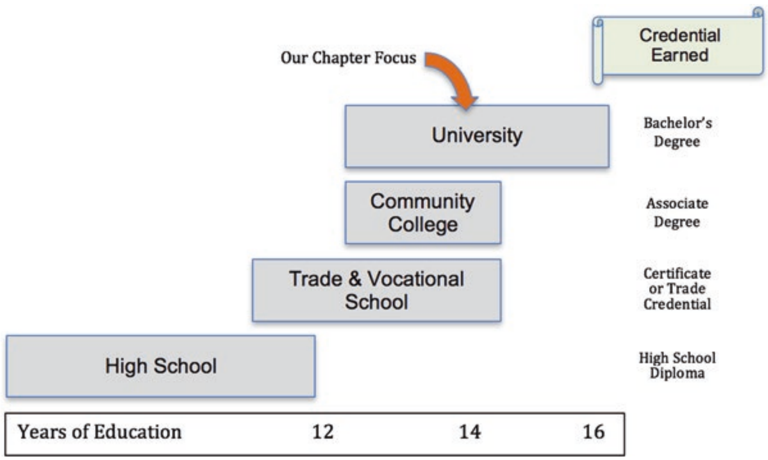

Fig. 18.1 Relevant educational system components and chapter focus

industrial and other technology graduates. While the overall number of business, engineering and technology (BE&T) baccalaureate graduates has the appearance of being sizeable at first glance, given the nation's population and economy, as well as the overall number of baccalaureate degrees awarded, the proportions (shown in Fig. 18.2.) constituted by BE&T fields seem quite modest – particularly when considering our society's needs for capable and conscious professionals.

There may be some grounds for optimism, however, in that the NCES (2013) also reported that the "number of bachelor's degrees conferred in the combined fields of engineering and engineering technologies increased by 8 percent between 2002–03 and 2007–08, and then increased a further 23 percent between 2007–08 and 2012–13". (p. 280).

The complexity of this technological human resource delivery system is depicted in Fig. 18.3 frequently used by Michael Dyrenfurth (since 1999) to depict the inflow of technologically capable professionals in our economic system. Careful readers will note that the figure does not explicitly depict business students but they would be at a par with engineers and technologists in Fig. 18.3.

Further complicating our picture of technologically capable people in the USA is the fact that our nation differentiates between engineers, engineering technologists and industrial, as well as other fields of technologists. While the general public typically is not aware of the nuanced differences crafted by various associations and leaders in their respective fields, often much is made of these differences in terms of accreditation, credentialing, and status.

Also necessary to understanding the nature of the American BE&T supply system is that one must additionally recognize the broad array of fields it addresses and the diversity of its organizational arrangements even within institutions. To this end, readers should note that various organizations gather data on the BE&T complex. Engineers Dedicated to a Better Tomorrow (2016), for example, report that there are 370 institutions offering engineering programs in the nation. Another organization, the American Society for Engineering Education annually compiles the Engineering

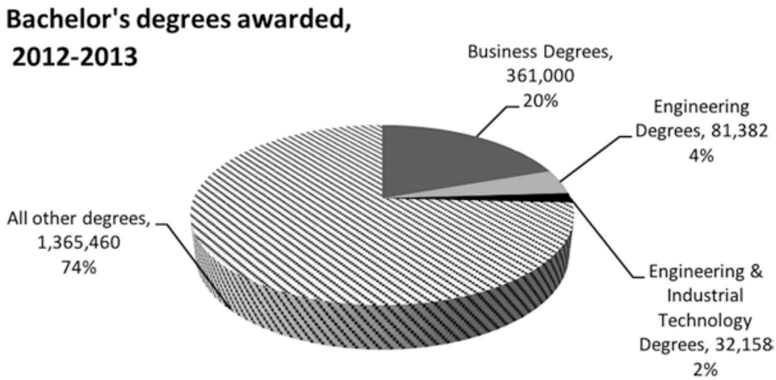

Fig. 18.2 BE&T bachelor's degrees as a proportion of the total number of baccalaureate degrees awarded (NCES 2013, 2016b)

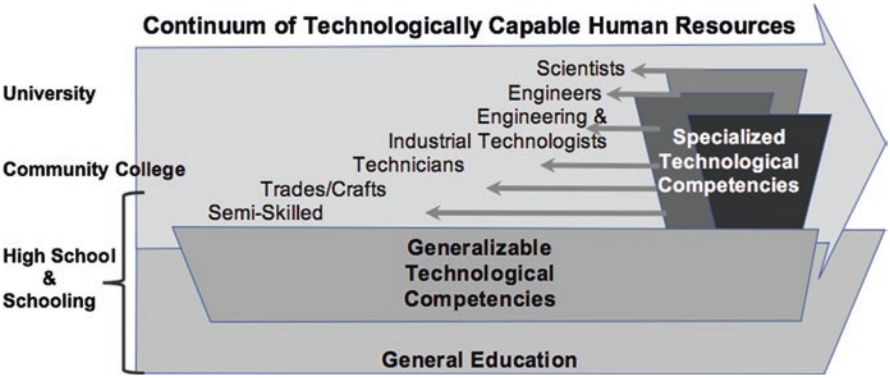

Fig. 18.3 Technological human resource delivery system

College Profiles & Statistics Book (Yoder 2016). This association's Engineering Technology Council and Engineering Technology Division publish a directory that lists 539 different technology programs in the nation at 469 different institutions. These programs are categorized into 27 different technology/engineering disciplines. Yet another association serving this field, the Association for Technology Management and Applied Engineering (ATMAE 2016), lists 179 accredited baccalaureate programs primarily in the technology fields. The business field is also organized into a wide range of disciplines. Its key educational association is the Association to Advance Collegiate Schools of Business (AACSB 2016b) which states:

> the following will be considered traditional business subjects: Accounting, Business Law, Decision Sciences, Economics, Entrepreneurship, Finance (including Insurance, Real Estate, and Banking), Human Resources, International Business, Management, Management Information Systems, Management Science, Marketing, Operations Management, Organizational Behavior, Organizational Development, Strategic Management, Supply Chain Management (including Transportation and Logistics), and Technology Management. (p. 7)

Their directory (AACSB 2016a) lists 517 institutions with accredited baccalaureate programs in the USA. It should be noted, however, that there exists debate within the profession as to what the purposes of these fields are. (Teehankee 2016).

Table 18.1 illustrates the rich range of traditional disciplines encompassed by the BE&T field. What is not shown, however, is the emerging array of innovative programs that typically address intersections of the traditional fields, e.g., systems engineering, biometrics technology, innovation management, etc.

In contrast to the maze of technology programs, the fields of business and engineering education seem more consistent and homogeneous. While certainly the business and engineering fields also exhibit within-group variance, the degree of such variance seems smaller than what the technology field exhibits.

To further illustrate the BE&T supply system, the authors also selected a set of flagship universities and assessed their involvement with BE&T. The findings,

Table 18.1 Traditional disciplines in BE&T fields

Engineering and technology disciplines	Business disciplines
Aeronautical engineering	Accounting
Air conditioning engineering	Business, business administration, industrial management, management
Architectural engineering	
Automotive engineering	Business analytics
Biomedical engineering	Economic consulting, economics, entrepreneurship, entrepreneurship and corporate innovation
Chemical engineering	
Civil engineering technology	Finance, financial analysis
Computer engineering	Human resource management
Construction engineering	Information systems, information technology
Drafting and design engineering	International business
Electrical Engineering	Law, ethics, and decision-making (LEAD)
Electromechanical engineering	Marketing, professional sales
Electronics engineering	Operations management
Engineering science technology	Public policy analysis
Environmental engineering	Real estate
Fire and safety engineering	Strategy and organizational management
General engineering technology	Supply chain information and Analytics, supply chain management
Graduate engineering technology	Sustainable business
Industrial engineering	Technology management
Industrial technology	AACSB (2016b)
Instrumentation technology	
Manufacturing engineering	
Materials/metallurgy engineering	
Mechanical engineering	
Other engineering technology	
Surveying engineering	
Technical management technology	
http://etd.wvutech.edu/curriculum_codes.php	

presented in Table 18.2 validate the conclusion that significant proportions of the selected university undergraduate enrollment are directed toward pragmatic purposes such as business, engineering and technology. The BE&T undergraduate proportions of these universities, as shown in the table's right hand column, range from 85% to 23% depending on the institution. The spectrum of programs serving the needs of business, industry and government includes applied science, engineering, engineering and industrial technology, technical education, business and management programs. A deeper analysis, looking at the nature of each individual program in every college at these institutions, would likely reveal even higher proportions of programs with a pragmatic focus.

Table 18.2 Selected flagship USA university program profiles

Name / Curricular emphasis / Region	Public/ private	Land Grant	UG Size/total	Colleges with UG programs in chapter focus [UG enrollment]	% of UG programs focused on BE&T
Notre Dame	Private	No	8000/12179	Mendoza College of Business [2050]	58%
UG emphasis				Science [1191]	
MidWest				Engineering [1203]	
				Architecture School [168]	
				Keough School of Global Affairs (new)	
University of Pennsylvania	Private	No	10,406/21441	Wharton School [1771]	64%
Grad emphasis				College of Arts and Sciences [6311]	
East				School of Engineering and Applied Science (SEAS) [1748]	
MIT	Private	No	4512/11319	Sloan School of Management [52]	85%
E&T grad emphasis				School of Science [724]	
East				School of Engineering [2455]	
				School of Architecture and Planning [37]	
				First year [1113]	
U of Michigan	Public	No	28,395/43625	A. Alfred Taubman College of Architecture and Urban Planning [432]	58%
Comprehensive				Stephen M. Ross School of Business [1505]	
MidWest				College of Engineering [5963]	
				College of Literature, Science, and the Arts [17321]	
IU	Public	No	36,419/42566	Kelley School of Business [5504]	33%
Comprehensive				School of Informatics and Computing [1398]	
MidWest				College of Arts & Sciences [10000]	

(continued)

Table 18.2 (continued)

Name / Curricular emphasis / Region	Public/ private	Land Grant	UG Size/total	Colleges with UG programs in chapter focus [UG enrollment]	% of UG programs focused on BE&T
North Carolina State University	Public Land Grant	Yes	25,176/34015	Poole College of Management [2557]	54%
Comprehensive				College of Agriculture and Life Sciences [2418]	
SouthEast				College of Design [581]	
				College of Engineering [6186]	
				College of Physical and Mathematical Sciences [898]	
				College of Textiles [926]	
Purdue	Public Land Grant	Yes	29,555/38770	Krannert School of Management [2511]	68%
E&T focus				College of Agriculture [2671]	
MidWest				College of Engineering [7928]	
				Purdue Polytechnic Institute [3313]	
				College of Science [3589]	
University of California-Berkeley	Public Land Grant	Yes	27,126/37581	Haas School of Business [700]	23%
Comprehensive				College of Chemistry [815]	
West				College of Engineering [3158]	
				College of Environmental Design [653]	
				College of Letters and Science [1900]	

Sources: data compiled spring 2016 from reported enrollments on university websites. For 1st year programs and colleges of arts and sciences reporting combined enrollments BE&T % is estimated at 50%

In summary, clearly the BE&T delivery system in the USA is a large, diverse, and complex enterprise with considerable within group variance. There is no single coordinating agency organizing the enterprise nor assigning purposes to the system's various institutions or programs. The next section will address the sources of purpose that exist for the three professional fields that are the focus of this chapter.

18.3 Purposes of Engineering, Technology and Business Programs

Given the world's increasingly complex and intertwined technological and environmental challenges as well as their interface with social issues such as equity, distribution of wealth, educational opportunity and quality, policy considerations and government, the authors of this chapter were driven to ask: How, in the targeted programs, are students exposed to concerns and initiatives other than those aimed at developing enhanced technocratic expertise/competence? Where are students encouraged to raise questions of values, ethics, social responsibilities of business, technological and engineering personnel? How are students provided with learning experiences that aim at the inculcation of such tendencies?

Simply put, we wanted to identify if and where students might be exposed to inputs and questions that would promote conscious capitalism and behaviors appropriate to the social responsibility of business and industry.

To this end we examined the stated purposes of selected flagship business, engineering and technology programs, in terms of the competencies and understandings they seek to develop in their graduates as well as the issues and broader purposes they seek to inspire their graduates to address. Additionally, the accreditation guidelines for business, engineering, and engineering technology programs were also similarly examined for such insights.

Engineering program accreditation criteria, as published by ABET (2015a), include reference to careers and the needs of the program's various constituencies. Additionally ABET specifies a set of outcomes (a-k) that include design to meet desired needs within realistic constraints (such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability); an ability to identify, formulate, and solve engineering problems; an understanding of professional and ethical responsibility; the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; and a knowledge of contemporary issues. It should also be noted that there is an active ongoing conversation as to the purposes of engineering education (Froyd et al. 2012; Koen 2010; Lönngren and Hanning 2013; Lucena et al. 2008; Seely 2005).

Engineering technology program criteria, also published by ABET (2015b), call for an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities; to design systems for broadly-defined engineering technology problems appropriate to program educational objectives; to identify, analyze, and solve broadly-defined engineering technology problems; an understanding of, and a commitment to, address professional and ethical responsibilities including a respect for diversity; and knowledge of the impact of engineering technology solutions in a societal and global context.

Business programs, as per the AACSB (2016b), are accredited pursuant to the program and learning criteria (among others) calling for general skills that include ethical understanding and reasoning (able to identify ethical issues and address the issues in a socially responsible manner) and reflective thinking (able to understand oneself in the context of society). Additionally, the required general business and management knowledge includes economic, political, regulatory, legal, technological, and social contexts of organizations in a global society; social responsibility, including sustainability; and ethical behavior and approaches to management, group and individual behaviors in organizations and society.

But, the potentially parochial and/or self-serving purposes espoused by professions, employers, and accrediting agencies are not the only voices relevant to the question addressed by this chapter. Other more general and ecumenical voices exist that should be considered. These voices have included: The Cardinal Purposes of Education (Commission on the Reorganization of Secondary Education 1918), the tension between employment-focused and education-focused higher education (*The Chronicle of Higher Education*) and Oxford's Institute for the Advancement of University Learning (2001) question about the purposes of higher education:

> What are the true purposes of higher education? Should it be education for employment? Or education for individual growth and satisfaction? Is higher education really about the promotion of civilization? Should we use education as a means to redress social inequality?[1]

While each source has its unique and valuable perspective, history certainly points to the importance of educational outcomes beyond those of mere employability.

18.4 Analysis of Program Requirements

The authors sought to ascertain the extent, if at all, to which ethics, corporate social responsibility and conscientious capitalism were actually reflected in the plans of study (POS) of undergraduates in an admittedly arbitrary sample of universities, but certainly all with well-recognized schools of business, and/or engineering and/or technology. These included MIT (Sloan School of Management, School of Humanities, Arts and Sciences), Indiana University (Kelley School of Business), Purdue University (Krannert School of Management, College of Engineering, Polytechnic Institute), Notre Dame University (Mendoza College of Business, College of Engineering), University of Michigan (Ross School of Business, College of Engineering), University of California-Berkeley (Haas School of Business, College of Engineering), Olin College (College of Engineering), Brigham Young University (Ira A. Fulton School of Engineering and Technology), California State

[1] https://www.learning.ox.ac.uk/media/global/wwwadminocuk/localsies/oxfordlearninginstitute/documents/supportresources/lecturersteachingstaff/resources/resources/Higher_Education_and_Higher_Learning.pdf

University-Fresno (Industrial Technology), Rochester Institute of Technology, University of Houston, University of Northern Iowa, University of Pennsylvania (Wharton School, School of Engineering) and North Carolina State University (Poole College of Management, College of Engineering). This selection included both private and public universities, land grant universities, and representation from across the USA.

Our analysis looked for specific mention of ethics, corporate social responsibility, conscious capitalism, sustainability and related phrases in the course titles of required and/or elective courses specified on the POS in BE&T. These plans were retrieved from each program's website content analyzed as described above. Tables 18.3, 18.4, and 18.5 present the highlights of our findings for each of the targeted programs (Business/Management, Engineering, and Technology). For each selected institution and program, we listed, in the middle column, courses plausibly linked or linkable to larger considerations such as *is this the right thing to do (even if legal), social responsibility, ethical issues, etc*. Our unit of analysis was the course title. This clearly resulted in a limitation in that it is entirely possible that instructors might address such larger concerns within courses where such attention is not obvious in the course title. But, the authors were looking for overt signals of such attention and we deemed inclusion of such a signal in the title as being a significantly more positive statement than mere infusion of a related activity in a class.

Recognizing the limitations imposed by both the intuitive selection of the sampled institutions and the data source of published plans of study, the authors supplemented the POS analysis with a number of discussions and interviews of leading BE&T deans, other administrators, and thought leaders as well as two case studies of exemplary programs. The intent of these two additional investigations was to gather qualitative insights to help us better understand what the undergraduate experience in BE&T was and to generally validate our impressions.

Our analysis revealed that the topic of ethics is widely addressed in engineering and to a lesser extent in business and technology programs. Perhaps this is a function of the extent to which ethics is addressed in accreditation standards. However, our analysis did not evidence widespread attention to the other issues that triggered this chapter. To be sure, the reviewed programs of study in each field clearly contained opportunities for addressing larger concerns – but were they systematically used to that end? Frankly we found no compelling evidence of this nor did our interviews suggest such opportunities were being exercised. We did learn of a very few examples contradicting the preceding generalization, e.g., Notre Dame, but they were clearly the exception. Philosophy was largely absent from most plans of study with the notable exception of Notre Dame which required not only two courses of philosophy but also two of theology.

We also noted widespread use of case studies, particularly in courses found on business POS, but little mention of this approach was noted in either engineering or technology program POS. In contrast, and of particular relevance to this chapter's impetus, several engineering programs have begun to address large societal issues under the rubric of Grand Challenges. Capstone courses were frequently found on

Table 18.3 Management/business program characteristics

Institution and name of business unit	UG courses in POS	Comment
University of Michigan	1. Business ethics and accountability	1. Center for positive organizations
Stephen M. Ross School of Business	2. The corporation in society	2. Center for social impact
	3. Business and leaders: the positive differences	3. Law is well represented in coursework
		4. School position speaks to Positive Business, i.e., that business is a force for good
University of California- Berkeley	1. Philanthropy course	1. States an explicit learning goal focused on ethics
Haas School of Business	2. Ethics course	
	3. Upper division electives:	
	1. Ethical leadership in business	
	2. Topics in corporate social responsibility	
	3. Sustainable business	
North Carolina State University	1. Ethics course requirement	1. States that there is an emphasis on ethical and global awareness
Poole College of Management	2. Additional humanities required	2. Permits a philosophy option
Purdue University	1. Technology and society	1. Management majors mean business. They effectively lead, coordinate and communicate innovative solutions in all aspects of an organization from strategy to operations to human resources. They are adaptable leaders with strong roots in analytics, complemented by solid communication skills that enable them lead in the business world.
Krannert School of Management	2. Ethics course not explicit	
	3. Elective: legal foundations of business	
Massachusetts Institute of Technology, Sloan School of Management	1. Business, government and society	1. State learning goal to "recognize ethical issues…demonstrate familiarity with alternative frameworks for ethical reasoning…implications of employing different ethical frames of reference when making business decisions"
	2. Ethics and the 21st century business leader (also honors)	
	3. Arts and humanities requirement	
Notre Dame University	1. Two courses in philosophy	1. Required university seminar that reinforces the ideals of the university (Catholic)
Mendoza College of Business Unit	2. Two courses in theology	2. Students required to live in residence which necessarily involve a seminar on faith and conscious living
	3. Intro to business ethics	
University of Pennsylvania, Wharton School	1. Corporate responsibility and ethics	1. Plan of study includes five electives enabling student to tailor their program

Table 18.4 Engineering program characteristics

Institution and name of engineering unit	UG Courses in POS	Comment
University of Michigan	1. Elective: sustainable design and manufacturing	1. Student educational outcomes include:
		"6] An understanding of professional and ethical responsibility
		...
College of Engineering		8] The broad education necessary to understand the impact of engineering solutions in a global and societal context"
University of California- Berkeley	1. No specified course in target focus	1. Design courses might address some of the areas of focus
College of Engineering		2. "You like the idea of solving complex problems for society"
North Carolina State University	1. Introduction to engineering and problem solving	1. Industrial engineering differs from other branches of engineering in two ways:
College of Engineering	2. Humanities elective (6)	2. It applies to all types of industrial, commercial and government activities
	3. Interdisciplinary perspectives (5)	3. It is the only branch that concerns itself with both people and things
Purdue University	1. Impact of engineering solutions	1. The mission of the College of Engineering is "To advance engineering learning, discovery, and engagement in fulfillment of the Land Grant promise and the evolving responsibility of a global university"
College of Engineering	2. Professional and ethical responsibility	
	3. Technology and values	
Massachusetts Institute of Technology	1. Humanities, arts, and social sciences (HASS) requirement (8)	1. Management in engineering is an elective that might address focus area

School of Engineering	2. Elective: environmentally benign design and manufacturing	2. "Mechanical engineering is concerned with the responsible development of products, processes, and power"
		3. "graduates will demonstrate … awareness of societal context, professional ethics"
		4. Sustainable and global development is an elective concentration
		5. Ethics and professional responsibility
		"As engineers, we have knowledge and skills well beyond those of most consumers of our work, who must trust us to produce systems that operate safely, reliably, and with minimal negative impact. Human lives can depend upon the quality of our work, and significant economic and environmental consequences can result from the things that we do. Therefore, we as engineers must always have an awareness of not only the benefits but also the dangers and limitations of systems that we design. We must never put forward results that we have not thoroughly evaluated, and we must never conceal the shortcomings of our products. This is the fundamental responsibility of our profession to our society"
Notre Dame University	1. University seminar	The program uniquely requires active co-curricular activities that reinforce the institution's mission
College of Engineering	2. Two philosophy courses	
	3. Two theology courses	

(continued)

Table 18.4 (continued)

Institution and name of engineering unit	UG Courses in POS	Comment
Olin College	1. Sustainable design	Engineering education at Olin is in the liberal arts tradition, with a strong emphasis on the Arts, Humanities, Social Sciences and Entrepreneurship. Olin is committed to preparing graduates who recognize the complexity of the world, who appreciate the relationship of their work to society, and who are dedicated to creative enterprises for the good of humankind. Olin College endeavors to provide its education at little cost to the student. Olin College strives to foster in students:
	2. History of technology: a cultural and contextual approach	A deep appreciation and comprehension of the principles of engineering analysis and design
	3. Culture and difference: an anthropological approach	A broad knowledge of social and humanistic contexts
	4. The human connection: tools and concepts from anthropology for understanding today's world	The ability to identify opportunities, articulate a vision, and see it to fruition
	5. Engineering for humanity	Dedication to intellectual vitality, community involvement and lifelong personal growth
	6. Issues in leadership and ethics	
University of Pennsylvania	1. Intro to engineering (addresses ethics)	The institution states it ensures its engineering and applied science students receive a fully rounded liberal arts education
School of Engineering	2. Humanities electives (2 CUs)	
	Social science or humanities elective (1 CU)	
	Social science, humanities or technology, business and societies electives (2 CUs)	

Table 18.5 Technology program characteristics

Institution and name of technology unit	UG Courses in POS	Comment
Brigham Young University	1. Manufacturing leadership	Educational objective:
Ira A. Fulton School of Engineering & Technology	2. Foundations of global leadership	Human and environmental factors — graduates will understand manufacturing's impact on society and the environment
California State University-Fresno	1. Humanities	Program emphasized technological and managerial competencies
Industrial Technology	2. Technology and society	
Purdue University	Transdisciplinary Program	1. Seminar courses will be taught by a rotating group of faculty from across disciplinary backgrounds, and will focus on engagement with a range of topics that allow them to explore the intersection between human cultures (humanities and behavioral and social science) and technology
Polytechnic Institute	1. Gateway to technology leadership and innovation	2. Student proficiency in each of eight primary competencies:
	2. Critical thinking and ethics	Design thinking
	3. Design thinking in technology	Systems thinking
	4. History of science and technology selective	Effective communication
	5. General education human Cultures: humanities selective	Envision and work independently
	6. Leadership and ethics	Social interaction and teamwork
	7. Tech and the global society	Ethical reasoning
		Innovation and creativity
		Disciplinary knowledge

(continued)

Table 18.5 (continued)

Institution and name of technology unit	UG Courses in POS	Comment
Rochester Institute of Technology	1. Liberal arts perspective requirement	The program also offers an opportunity to explore degree routes for a year
College of Applied Arts and Sciences	2. Liberal arts elective	
University of Houston	1. Language, philosophy and culture	The program states it is devoted to the application of engineering principles and the implementation of technological advances that benefit humanity, engineering technology professionals apply their knowledge of mathematical and natural sciences gained through higher education with practical experience
College of Technology	2. Impact of modern technology on society	
	3. Organizational decisions in technology	
University of Northern Iowa	1. Liberal arts core	Offers both Technology Management and Manufacturing Technology programs among others
Department of Technology (College of Humanities, Arts and Sciences)	2. Technology in society and organizations	
	3. Introduction to Sustainability	
	4. Living in our techno-social world	

Massachusetts Institute of Technology	1. One STS Tier I subject*	1. Address two basic, interrelated questions: how did science and technology evolve as human activities, and what role do they play in the larger civilization? The STS perspective is crucial to understanding major events of our time (war and conflict, the economy, health, the environment) and to addressing these and other major public issues (privacy, democracy, education)
School of Humanities, Arts, and Social Sciences	Technology in American History(CI-H)	
Science Technology and Society	Finance and society (CI-H)	
	The rise of modern science(CI-H)	
	Intersections: science, technology, and the World	
	Bioethics (CI-H)	
	Technology in History (CI-H)	
	Technology and experience (CI-H)	
	Evolution and society (CI-H)	
	Science in action: technologies and controversies in everyday life	
	2. One STS tier II subject (examples)	
	Gender in science, technology, and environment	
	Making the modern world: the industrial revolution in global perspective	
	History of Manufacturing in America	
	The civil war and the emergence of modern America: 1861–1890	
	Energy, environment, and society	
	Science communication: a practical guide	
	Einstein, Oppenheimer, Feynman: Physics in the 20th Century	
	Technology and self: science, technology, and memoir	
	Technology and self: things and thinking	
	Language and technology	
	Cross-cultural investigations: technology and development	
	Art, craft, science	
	Technology and culture	
	Science, technology, and public Policy	
	Foundations of information policy	
	Five other STS subjects forming a coherent group of study	
	Critical Issues in STS	

engineering plans of study and often they involved design and/or problem solving projects. To a slightly lesser degree these approaches were also used in technology programs.

We did find clear evidence of programs in each of the three fields being responsive to accreditation-driven requirements so perhaps, if the larger concerns are to be addressed, they would first need to be incorporated in such standards. The BE&T POS certainly seemed to address the pragmatic needs of business and industry – a fact not surprising since each of these fields makes extensive use of advisory committees to guide curriculum development. Similarly, the accreditation organizations in each field also involve significant private sector participation.

The authors therefore concluded that accreditation is critically important to establishing the nature of student experience. Repeatedly we saw evidence of accreditation standards wording reflected in BE&T course titles and descriptions. In sharp contrast, references to corporate social responsibility and conscious capitalism were very scarce.

18.5 Field Specific Exemplary Approaches

Two vignettes, one from an exemplary program in Engineering (Olin College), and one from Technology (The Purdue Polytechnic Institute) are presented to highlight exemplary innovative approaches and reflect on their addressing of larger concerns and conscious capitalism. The descriptions of each of these exemplary programs will address their curriculum and program structure, a depiction of key instructional and learning activities that cause students to consider the larger purposes of business, engineering and technology, and examples of how the grand challenges facing society are grappled with by students and faculty.

18.5.1 Olin College: Innovation in Higher Education

Olin College located in Needham, Massachusetts USA, is a 4-year private university created in 1997 with its first graduating class in 2002, when the Olin Foundation decided to place all its wealth into a single effort to transform engineering education. For many years the Olin Foundation donated money to engineering programs at colleges and universities throughout the USA. The foundation directors became increasingly frustrated with not having any lasting or meaningful changes to engineering education through their donations. The foundation decided to take a very bold step in creating an engineering college with its remaining assets and hired Dr. Richard Miller to lead the effort. Dr. Miller was the engineering dean at the University of Iowa and he began the task of creating a new kind of engineering education degree program more aligned with the needs of industry and the nation.

The foundation began by rethinking higher education and the institution of universities in the USA. Examples of this rethinking include faculty not having tenure, no academic departments, and everything has an expiration date. They believe that young people are more capable of learning than we think and they can take more responsibility for their own learning. The founding precept for Olin College is intended to be different in order to become an important and sustained contributor to the advancement of engineering education in the USA and the world. Olin is intended to become an education laboratory for engineering education. The curriculum is very hands-on and project-based giving students multiple opportunities to practice engineering while in college.

Olin College has become noted as one of the top undergraduate engineering programs in the USA based on various rankings, such as US News and World Report's Annual Rankings. The current enrollment is approximately 380 students who major in engineering disciplines of Electrical and Computer Engineering and Mechanical Engineering, with concentrations in bioengineering, computing, design, materials science, robotics and systems. The ABET accredited programs are interdisciplinary in nature, project-based with an emphasis on innovation and with a rigorous foundation in science, maths and engineering fundamentals. Many classes are taught in a studio environment where students have dedicated spaces for project work.

The curriculum philosophy of Olin College is based on a recognition that students should not be passive learners taught by the "sage on the stage" in rows of seats and use of whiteboards to supplement lectures. Faculty are now coaches serving as mentors in the learning process with the goal of having students show what they can do with what they know. Students explore their level of knowledge and creativity by working on research projects with faculty, independent studies, and Passionate Pursuits. The Passionate Pursuits program encourages students to pursue their personal interests by choosing a semester long project where they set their own goals with guidance from a faculty member. Students also have a capstone experience through the Senior Capstone Program in Engineering (SCOPE) program. SCOPE is an industry sponsored team project over the course of a full academic year to provide solutions to real-world industry problems. The Olin faculty work in an integrated environment organized in a single department. Faculty in the department are engineers, scientists, mathematicians, liberal arts, entrepreneurs, and designers, all working together in integrated classrooms. Engineering is integrated with maths, science, and humanities.

Olin indirectly addresses conscious capitalism and corporate social responsibility through the requirement that all Olin students complete a concentration either in the Arts, Humanities, and Social Sciences or entrepreneurship. These courses are taught by Olin faculty and through cross-registration with Olin's partner universities: Babson College, Brandeis University and Wellesley College. In addition, interdisciplinary classes are offered that connect engineering, maths and science to the arts and humanities.

18.5.2 The Purdue Polytechnic Institute

The Purdue Polytechnic Institute is a bold initiative to address many of the pressing challenges facing higher education in this digital age and provide a better prepared science, technology, engineering and mathematics (STEM) workforce for our nation through the transformation of traditional teaching and learning practices.[2] It is attempting to transform higher education from within by changing an entire academic college with a total of over 4000 students at its main campus in West Lafayette, Indiana, with about 180 faculty and 150 staff. This initiative is guided especially by the works and research of the Association of American Colleges and Universities (AAC&U) (2013) on "essential learning outcomes" which are best developed by a liberal education and their *Key Findings from 2013 Employees*. These essential learning outcomes are delivered through high impact teaching practices.

The college's transformation plan focuses on six intersecting areas with a goal to have most work completed by Fall 2017:

1. Curriculum Innovation
2. Teaching and Learning Method Innovation
3. Use-Inspired Research
4. K-12 STEM Education & URM Opportunities
5. Faculty Professional Development
6. Modernization of Learning Spaces

18.5.2.1 Curriculum Innovation

Curriculum innovation is being driven by the needs of industry and delivered through curriculum and learning transformation that prepares a T-shaped professional. The curriculum is being transformed through new application-oriented degree programs and options where students learn the fundamentals or theory of computer science for the computing-related degrees, engineering fundamentals for the engineering technology degrees, and fundamentals of business and management practices for the applied management degrees. Students then learn how to apply the discipline fundamentals to specific applications in their respective fields and industry sectors that are growing rapidly, such as advanced manufacturing, computing and information technology, construction, and aviation. These distinctive degree programs are to prepare a workforce in the STEM disciplines for the digital age in which graduates learn by doing and are measured for success by "what they can do with what they know" through competency-based instruction.

The overall goal is to prepare graduates as T-shaped professionals. T-shaped professionals are characterized by their deep disciplinary knowledge in at least one

[2] The authors of this chapter are members of the Polytechnic's faculty, Professor Emeritus and Dean respectively

area, an understanding of systems, and their ability to function as "adaptive innovators" and cross the boundaries between disciplines.

The vertical bar of the "T" represents the disciplinary specialization and the deep understanding of one system. Systems describe major industry sectors, such as transportation, energy, design and manufacturing, food, and healthcare, that impact quality of life. The defining characteristic of the "T-shaped professional" is the horizontal stroke, which represents one's ability to collaborate across a variety of different disciplines.

The "T-shaped" graduate has the combination of deep vertical knowledge in a particular STEM domain with a broad set of horizontal skills such as teamwork, communications, creativity and problem solving, facility with data and technology, an appreciation of diverse cultures, and advanced literacy skills. These horizontal skills are gained from internships, co-op programs, community service learning programs, study-abroad programs, undergraduate research programs to supplement coursework, and the integration of humanities in the curriculum. The humanities are being taught in an integrated fashion in their major courses so that these topics are viewed by the student and faculty as being integral to the learning of their discipline rather than simply as "general education."

18.5.2.2 Teaching and Learning Innovation

Based on learning theory and effective use of technology, teaching and learning practices are being changed to better deliver instruction and improve the learning experience for the student. Teaching and learning practices being implemented in the Polytechnic include:

- *Theory-based applied learning* – core to the Polytechnic learning experience, applied learning is a powerful lab-centric approach that helps students understand and retain concepts to solve problems.
- *Team project-based learning* – team projects are a cornerstone to the transformation, exposing students to team dynamics, team deadlines, and team problem-solving. This is particularly effective when implemented through studio and design lab learning spaces.
- *Modernized teaching methods* – instruction transitions toward a model known as "active learning" that place students at the center of the learning environment with faculty serving more as mentors and coaches. Advanced methods, such as "Learning in Context", provide a richer learning experience that synchronizes the purpose and timing of specific learning topics.
- *Integrated humanities studies* – through integrated humanities study and using learning-in-context methods, students will learn horizontal attributes of the T-shape to become better communicators, team participants and leaders, and creative problem solvers.

- *Competency credentialing* – measuring student level of learning by showing what they can do and less emphasis on test taking.
- *Senior capstone projects* – students have real projects with real clients that span two semesters providing a very deep learning experience.
- *Internships* – embedding internships into the curricula to expand student knowledge and skills in a real-world setting and set a solid foundation for employment after graduation.
- *Global Cultural Immersion* – students can choose to gain enriched global perspectives through study abroad, international internships and senior capstone projects, or other types of global projects.
- *Faculty-to-student mentorship* – Polytechnic students will be paired with faculty and staff members for professional guidance and support while students at Purdue.
- *Business practices and principles* – students learn the foundations of business practices, such as finance, marketing, sales, and HR.

18.5.2.3 Application-Oriented (Use-Inspired) Research

The transformation of the Purdue Polytechnic Institute from the College of Technology is a major undertaking that affects all aspects of a contemporary higher education academic college. Much of the publicity surrounding the transformation has been focused on the transformation of the undergraduate curriculum. Research is a core component of the Polytechnic now and will continue to grow into the future. The college has a unique role to play in research at a R1[3] university in the twenty-first century.

Research in "science" is the discovery of new knowledge, research in "engineering" is the creation of new artifacts, and research in the "Polytechnic" is the discovery and implementation of new solutions through the integration of science discoveries and engineering artifacts. Use-inspired basic research is undertaken to understand fundamental laws and principles, but the inspiration of such research is not to create new knowledge but "to solve practical problems". Industry has a high interest in this type of research, and we are seeing that interest grow with 55% of the college's $21 million in research awards last year coming from industry. This practical problem-solving approach aligns perfectly with the undergraduate curriculum goals and provides rich opportunities for undergraduate students to engage in research.

[3] R1 refers to a category of doctoral universities that award a minimum of 20 research/scholarship doctoral degrees and have the highest level of research activity. This classification system was established by the Carnegie Commission on Higher Education (Adapted from http://carnegieclassifications.iu.edu/classification_descriptions/basic.php)

18.5.2.4 K-12 STEM Education and Opportunities for Under-Represented Populations

The Purdue Polytechnic Institute recognizes the need to better prepare K-12 students for college and work in high-demand STEM fields.[4] The Purdue Polytechnic Indianapolis High School is a new charter school specifically designed to develop a new generation of skilled talent by seamlessly transitioning students from high school and post-secondary education to high-wage, high-demand jobs with a focus on preparing underserved students. This will be unlike any educational experience offered in Indiana and, potentially, the nation. The rigorous curricula and learning environment are built on strong industry relationships, an innovative partnership with the Purdue Polytechnic Institute and Purdue University, and the local community, with a goal to ensure a diverse student body succeeds in the digital economy.

18.5.2.5 Faculty Professional Development

Faculty are going through an extensive development program to change their teaching from “sages on the stage” to “coaches and mentors.” All faculty will be going through the university’s IMPACT program as well as specialized workshops and mentoring to address the specific challenges we face in transforming the learning experience for our students. The leadership team for the college is also going through an extensive development program to increase collaboration and trust within the group and with the faculty.

18.5.2.6 Modernization of Learning Spaces

A transformed learning environment requires transformed learning spaces. Since there is less emphasis on lectures and more on active and collaborative team-based learning, the learning spaces have to change to a more open-space architecture to accommodate small-team gatherings. Space is being remodeled in the primary PPI building (Knoy Hall), and a study is underway to finalize additional space needs in support of the transformation and to identify potential space solutions.

The Polytechnic Institute at Purdue addresses conscious capitalism and corporate social responsibility through its close alliance with the College of Liberal Arts at Purdue. Courses are being co-developed by technology and liberal arts faculty, in history and philosophy for example. Efforts to integrate the humanities into the curriculum through efforts, such as “writing across the curriculum”, are being added to the curriculum transformation efforts. Business principles are also being integrated into the curriculum that will include topics related to capitalism and social responsibility.

[4] K-12 refers to school grades Kindergarten to 12th Grade

18.6 Conclusions, Recommendations and Questions for Further Research and Contemplation

18.6.1 Conclusions

The findings yielded by our data collection and analysis evidence a somewhat contradictory set of inputs. Academic leaders seem quite aware of the need to address ethics, social concerns and awareness, issues and value dimensions, i.e., larger outcomes of their programs and students' experience. Yet the analysis of the plans of study reveals relatively little overt incorporation of such directions into the coursework experienced by students. Of course, the authors recognize that specific learning activities within a course might address the larger outcomes even if the actual course title and/or catalog description might not evidence the same. But, we would argue, if the focus was important enough perhaps the title and description should indeed highlight it.

Conscious capitalism and corporate social responsibility might be important concepts in today's and tomorrow's world but one could not tell it from looking at the programs experienced by BE&T baccalaureates. To be sure, they are likely to have had exposure, usually in a single course, to the intersection of ethics and their field of study but probably little else. That is, unless one counts on a few scattered humanities courses, mostly elective choices, to deliver the perspective that formed the impetus for this chapter. Even then, could a course or two actually accomplish the goal?

Alan Cheville (2012) in a provocative IEEE article also recognized that more systematic and powerful efforts were needed. He stated:

> Beyond entities, ongoing dialogs also drive outcomes, particularly in programs that focus on engineering in crosscutting contexts. Such contexts include sustainability to mitigate risks arising from overpopulation and resource depletion [50] as well as globalization; the increasingly global practice of engineering in a Flat world [51]. Service learning programs such as Engineering Projects in Community Service (EPICS) [52] and Engineers Without Borders also fall into this category. Another dialog has arisen around the NAE's Fourteen Grand Challenges [53]. About a dozen universities support grand challenge scholars programs that engage students in the larger context of engineering [54]. A key element of such programs is to consider engineers as a critical part of a larger interdisciplinary ecosystem (ibid, p. 1365).

The authors of this chapter conclude that the evidence shows that our core BE&T disciplines take precedence over the larger purposes of ethics, conscious capitalism and corporate social responsibility. This is not surprising given the de-emphasis of the liberal arts on most college campuses that have large engineering, technology and business programs. As technology and business practices become more sophisticated and demanding, college curricula in engineering, technology and business have focused more teaching and learning time on their core discipline. Typically, attempts to address conscious capitalism and corporate social responsibility have been through "bolt on" additions to the curricula, which result in minimal impact.

In sharp contrast, the two exemplary programs we highlighted earlier in this chapter are making a conscious effort to address conscious capitalism and corporate social responsibility through their curriculum transformation efforts. "Bolt on" curricula additions are not used in these programs. These exemplary programs understand that, to truly address the larger purposes, you have to look at the entire curriculum in a holistic manner, then design ways to integrate these topics into the curriculum that span multiple courses across multiple semesters, and through a close collaboration with liberal arts faculty.

18.6.2 Recommendations for Practice

We conclude this chapter with a set of what we hope to be provocative and forward looking recommendations. The first is to recognize that the inculcation of attitudes and the generation of a value system require extended and consistent learning and interaction. To that end, we recommend establishing fewer, but larger and more significant, rather than more reductionist outcomes. Included of course must be an outcome specifically targeted on corporate social responsibility, ethics and conscious capitalism.

We should also recognize that our *laissez faire* approach to letting students freely choose the few humanities courses they are required to take is not effective. Our recommendation is to be more prescriptive in which humanities courses are useable in a POS and when they must be taken. Therefore, we recommend placing philosophy (emphasizing epistemology and axiology) and issues courses early in the POS sequence rather than just pragmatic courses. We also suggest incorporation and extensive use of case studies of exemplars of ethics, corporate social responsibility and conscious capitalism throughout the 4-year curriculum.

Our final, and most important, recommendation is that the BE&T professions stop looking for "bolt on" solutions, i.e., individual courses or singular approaches, and instead look for long-term (i.e., 4-year) pervasive transformation and integration strategies that include a systematic interaction with, and involvement of, liberal arts/humanities programs and faculty. By long term we mean to employ scaffolding and a spiral curriculum design, as conceptualized in Fig. 18.4, to result in a more significant impact on student values. In essence we suggest the need to plan for and deliver a small number of competency vectors directed not only at the pragmatic competence needed by our times but also, at least some, directed at the larger outcomes in the realm of ethics, corporate social responsibility, and conscious capitalism.

Our professions should also note the need to synergistically augment the scaffolded curriculum with out-of-class learning experiences such as learning communities, field or issue-based residence arrangements, and multi-year infusion initiatives (NAE 2016). We need to ensure that every pragmatic competence building course includes at least one infusion of activities addressing corporate social

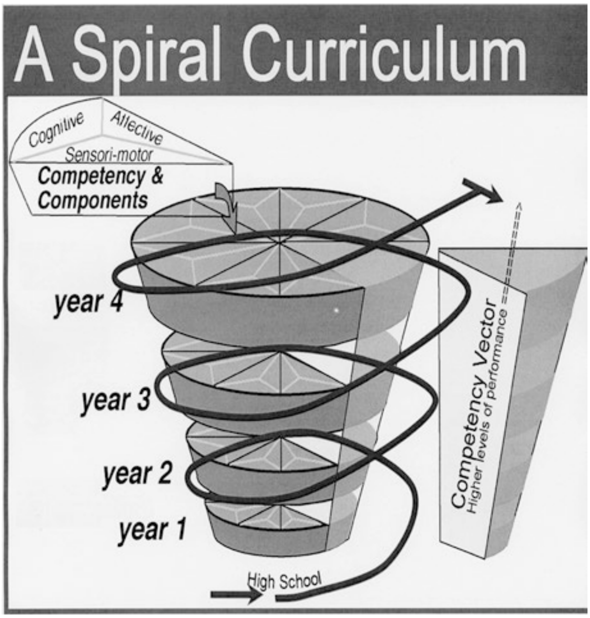

Fig. 18.4 Spiral curriculum concept

responsibility and/or ethics and/or conscious capitalism. Furthermore, these activities should be planned and coordinated across the program in order to contribute to the spiral curriculum.

18.6.3 Further Research

But, despite all of what we know about effective preparation for the BE&T professions, some of which has been highlighted in this chapter, we must also acknowledge that there remains much that we do not know yet. Therefore, we recommend three large-scale research initiatives with promising potential to enable moving our professions' preparatory practice forward.

1. There is considerable effort directed toward assessing and enhancing the public's understanding of engineering and technology (Committee on Public Understanding of Engineering 2008) but a commensurate effort needs to evolve aimed at changing the engineer, technologist and business professionals' understanding of society;
2. Research how students establish their value and ethical systems and apply them in their early career life. Similarly establish how senior professionals in BE&T also apply them;
3. Conduct longitudinal studies of the exemplary programs in each BE&T field and incorporate assessments of the larger outcomes. We need to look at additional

exemplary programs, including the outstanding ones across the world, to learn how they have addressed these topics. Furthermore, we should not be parochial and look only at exemplary BE&T programs because we might well learn much from examining lessons from programs producing compassionate, caring and critically thinking professionals such as ministers and social scientists.

References

Abowitz, K. A. (2008). On the public and civic purposes of education. *Educational Theory, 58*(3), 357–376.

Accrediting Board for Engineering and Technology (2015a). *Criteria for accrediting engineering programs*. Effective for reviews during the 2016–2017 accreditation cycle. Baltimore: http://www.abet.org/wp-content/uploads/2015/10/E001-16-17-EAC-Criteria-10-20-15.pdf

Accrediting Board for Engineering and Technology (2015b). *Criteria for accrediting engineering technology programs*. Effective for reviews during the 2016–2017 accreditation cycle. Baltimore: http://www.abet.org/wp-content/uploads/2015/10/T001-16-17-ETAC-Criteria-10-16-15.pdf

Association of American Colleges and Universities (2013). Key findings from 2013 survey of employers. Washington, DC: Author. Retrieved from https://aacu.org/sites/default/files/files/LEAP/KeyFindingsfrom2013SurveyofEmployers.pdf

Association of Technology, Management and Applied Engineering. (2016). List of accredited programs. Elmhurst: Author. Retrieved from http://c.ymcdn.com/sites/www.atmae.org/resource/resmgr/docs/accredprograms_by_state.pdf

Association to Advance Collegiate Schools of Business. (2016a). *List of accredited institutions*. Tampa: Association to Advance Collegiate Schools of Business Retrieved from http://www.aacsb.edu/accreditation/accredited-members/global-listing.

Association to Advance Collegiate Schools of Business. (2016b). *Eligibility procedures and accreditation standards for business accreditation*. Tampa: Association to Advance Collegiate Schools of Business Retrieved from http://www.aacsb.edu/ ~/media/AACSB/Docs/Accreditation/Standards/2013-bus-standards-update.ashx.

Cheville, A. (2012). Engineering education today: Capturing the afterlife of Sisyphus in five snapshots. *Proceedings of the IEEE, 100*, 1361.

Christensen, C. M., & Eyring, H. J. (2011). *The innovative university: Changing the DNA of higher education from the inside out*. San Francisco: Jossey-Bass.

Commission on the Reorganization of Secondary Education. (1918). *Cardinal principles of secondary education*. Washington, DC: National Education Association.

Committee on Public Understanding of Engineering Messages. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: National Academies Press https://www.nap.edu/catalog/12187/changing-the-conversation-messages-for-improving-public-understanding-of-engineering.

Delbanco, A. (2014). *College: What it was, is, and should be*. Princeton: Princeton University Press.

Dyrenfurth, M. (1999). Engineering & technology – the nature of the relationship, session I: Issues in the foundations of the profession. Mississippi Valley Technology Teacher Education Conference, 86th Conference, St. Louis, Missouri.

Engineers Dedicated to a Better Tomorrow. (2016). *The online guide to engineering schools*. Menlo Park: Engineers Dedicated to a Better Tomorrow Retrieved Aug 30, 2016 from http://www.dedicatedengineers.org/.

Froyd, J.E., Wankat, P.C., Smith, K.A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE, 100*, Centennial Special Issue, May 13, https://doi.org/10.1109/JPROC.2012.2190167.

Institute for the Advancement of University Learning. (2001). *Paper 1: Higher education and higher learning*. Oxford: University of Oxford Retrieved from http://www.learning.ox.ac.uk/media/global/ wwwadminoxauk/localsites/oxfordlearninginstitute/documents/supportresources/ lecturersteaching staff/resources/resources/Higher_Education_and_Higher_Learning.pdf.

Koen, B. V. (2010). Quo Vadis humans? Engineering the survival of the human species. In I. van de Poel & D. Goldberg (Eds.), *Philosophy and engineering: An emerging agenda*. New York: Springer.

Lönngren, J., & Hanning, A. (2013). Is it sustainable to educate engineers? Reflections on the purpose of engineering education. Retrieved from http://www-csd.eng.cam.ac.uk/proceedings-of-the-eesd13-conference-cambridge-2013-v-2/keynote-synopsis-lonngren-and-hanning/view.

Lucena, J., Downey, G., Jesiek, B., & Elber, S. (2008). Competencies beyond countries: The re-organization of engineering education in the United States, Europe, and Latin America. *Journal of Engineering Education, 97*, 433–447. https://doi.org/10.1002/j.2168-9830.2008.tb00991.x.

Mackey, J., & Sisodia, R. (2014). *Conscious capitalism*. Cambridge, MA: Harvard Business Review Press.

National Academy of Engineering, Infusing Ethics Selection Committee. (2016). *Infusing ethics into the development of engineers: Exemplary education activities and programs*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21889.

National Center for Education Statistics. (2013). *Digest of education statistics: 2013*. Washington, DC: US Department of Education, National Center for Education Statistics Retrieved July 30, 2016 from http://nces.ed.gov/programs/digest/d13/ch_3.asp.

National Center for Education Statistics. (2016a). *Condition of education 2016*. Washington, DC: US Department of Education, National Center for Education Statistics Retrieved July 30, 2016 from http://nces.ed.gov/pubs2016/2016144.pdf.

National Center for Education Statistics. (2016b). *Fast facts: Most popular majors*. Washington, DC: US Department of Education, National Center for Education Statistics Retrieved July 30, 2016 from https://nces.ed.gov/fastfacts/display.asp?id=37.

Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for life and work developing transferable knowledge and skills in the 21st century*. Washington, DC: National Research Council.

Rego, M. A. S. (2014). Purposes of the university and employability challenges in higher education (Fines de la Universidad y Retos de la Empleabilidad en la Educación Superior). XIII international congress on theory of education. XIII Congreso Internacional de Teoría de la Educación. *Procedia – Social and Behavioral Sciences, 139*, 16–25.

Saichie, K., & Morphew, C. C. (2014). What college and university websites reveal about the purposes of higher education. *The Journal of Higher Education, 85*(4), 499–530. https://doi.org/10.1353/jhe.2014.0024 Retrieved July 2016 from http://muse.jhu.edu/article/548203.

Schwab, K. (2016). *The fourth industrial revolution*. Geneva: World Economic Forum.

Seely, B. E. (2005). Patterns in the history of engineering education reform: A brief essay. In *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.

Teehankee, B.L. (2016). Reclaiming the purpose of business education. Business world online posted on February 25, 2015 10:10:00 PM http://www.bworldonline.com.

The Economist. (2009). Triple bottom line. Online extra http://www.economist.com/node/14301663.

Yoder, B. L. (2016). *Engineering by the numbers*. Washington, DC: American Society for Engineering Education Retrieved from https://www.asee.org/papers-and-publications/publications/college-profiles/15EngineeringbytheNumbersPart1.pdf.

Michael Dyrenfurth Ph.D. Industrial Education and Technology & Higher Education, Bowling Green State University; M.Ed. Industrial Education, University of Alberta-Edmonton. Professor Emeritus, Department of Technology Leadership and Innovation, Purdue Polytechnic Institute, Purdue University, West Lafayette, Indiana, USA. He has been an active leader in the American Society for Engineering Education's Entrepreneurship & Innovation and Engineering Technology divisions, in the Epsilon Pi Tau honorary for professions in technology, and in establishing the World Council of Associations for Technology Education. His current research focus is on the interface of technological innovation with cognitive science. His publications include Grimson, W., Dyrenfurth, M., & Murphy, M. (2009). Liberal Studies in Engineering & Technology. Chapter 8 in S.H. Christensen, B. Delahousse, & M. Meganck, (Eds.) (2009). *Engineering in Context.* Aarhus, Denmark: Academica and Dyrenfurth, M., & Barnes, J. (2015). *The innovation – cognitive science interface: Implications for engineering and technology education*. Paper delivered at the SEFI (European Engineering Education Annual Conference, July 2, 2015, Orleans, France.

Gary Bertoline Dean of the Purdue Polytechnic Institute and a Distinguished Professor of Computer Graphics Technology and Computer & Information Technology at Purdue University, West Lafayette, IN USA. He earned his PhD at The Ohio State University and was on the faculty in the College of Engineering for 3 years before coming to Purdue University in 1990. From 2002 to 2006 in his role as Associate VP and Director, he led the creation of the Rosen Center for Advanced Computing and the Envision Center for Perceptualization. Currently he leads the Polytechnic initiative at Purdue, which is a major effort to transform the college's curricula and learning experience for the students to better prepare graduate for life and work in the digital age. He has authored and co-authored seven textbooks and numerous papers in journals and trade publications on engineering and computer graphics, computer-aided design, and visualization research. Gary's research interests are in scientific visualization, interactive immersive environments, distributed and grid computing, workforce education and STEM education

Chapter 19
Educating Future Engineer-Managers About Corporate Social Responsibility Following the *École de Montréal*'s Perspective

Lovasoa Ramboarisata and Corinne Gendron

Abstract Relying on an assessment of CSR education in highly-ranked business schools and our own experience at the specialized MBA in Science and Engineering and in Technology Management at the business school of the University of Québec in Montreal, we argue that teaching CSR to engineer-managers should not be misconstrued as a plea for moral rectitude, or as a limited utilitarian recipe for managing issues or stakeholders—as it too often is. Rather, it should allow students to recognize corporations as social institutions so that they can gauge their impact on a social scale and better weigh the values that inform them. It should as well make them aware of the dilemmas engineers are facing as they practise the managerial profession. Our approach is founded on the premises of the Montreal CSR School, a socio-critical perspective, at a junction of the French and Canadian CSR scholarships.

Keywords Engineering-management · Business schools · MBA · Ethics · CSR · Sustainable development

19.1 Introduction

Progress has been made in integrating ethics and introducing the principles of corporate social responsibility (CSR) and sustainable development (SD) into engineering curricula. However, future engineer-managers still need to be provided with the needed skills which should allow them to reflect more about both their own role and

---

An earlier version of this chapter was presented at the 7th Conference of the EESD (Engineering Education for Sustainable Development) at the University of Cambridge in September 2013.

L. Ramboarisata (✉) · C. Gendron
Département de stratégie, responsabilité sociale et environnementale, École des sciences de la gestion, Université du Québec à Montréal, Montréal, Canada
e-mail: ramboarisata.lovasoa@uqam.ca; gendron.corinne@uqam.ca

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_19

their businesses' role in society. Engineers and scientists holding management positions in businesses need to be equipped with the knowledge and the competencies that may allow them to navigate the challenges of contributing to a social progress, served by a healthy and ecologically-sound economy. Moreover, they need to understand the broader context of capitalism and businesses' discourses and practices. In most of the private sectors hiring engineering-management graduates (healthcare, manufacturing, information technology or IT, pharmaceutical, biotechnology, construction, energy) as well as in public administration (cities, ministries and governmental agencies), many issues are critical at the system level, and their causes are rooted in socio-political, historical, and cultural contexts. Consequently, they cannot be solely addressed by technical solutions at the organizational level or code of conduct at the professional one. Thus, they need to be understood beyond the duties of engineers toward their profession and their organizations. Moreover and most importantly, future engineer-managers should be aware of the assumptions underlying different views of ethics, CSR, and SD, as well as the multiple tensions faced by businesses, and the complexity of the environment within which ethical and responsibile managerial decisions have to be made.

This chapter discusses the role of business schools (or management schools[1]) in educating engineer-managers about ethics, CSR, and SD. The following facts allow us to state that these schools have at least some role to play in such an endeavour:

- More engineers and students with other scientific backgrounds are getting graduate management training (Master of Business Administration or MBA and Master of Science or MS); and top management schools are multiplying their specialized program offerings to engineers and scientists.
- The engineering community has long been aware of the social responsibility the engineering profession entails. Discussion about engineering ethics, which goes beyond and challenges self-interest, utilitarian, and normative approaches, has been longstanding within both engineering academia and professional associations. Thus, engineers have been expecting and are expected to be adequately and sufficiently educated about those subjects. The pressure to provide such a thorough and relevant socially and ethically-sound education is even greater for business faculty who should train future engineer-managers to run large corporations and public organizations.

In this chapter, we first review the above-mentioned facts (Sects. 19.2 and 19.3). Then, we explain that extending the domain of ethics, CSR, and SD education beyond the utilitarian and normative "business-case" and adopting a critical-pragmatic turn in pedagogy seem to remain an unfulfilled agenda. This observation is based on our assessment of the so-called "responsible-management education" in highly-ranked business schools (Sect. 19.4). In the next section, we present our instructional approach at the business school of the University of Québec in Montreal as a potentially relevant way to meet the challenge of a pragmatic-critical turn in engineer-managers' education (Sect. 19.5). Our approach is informed by the

[1] We will use «business schools» and «management schools» interchangeably.

premises of the *École de Montréal* (CSR School of Montreal). We view ethical engineer-managers as reflective practitioners, able to conduct inquiry toward the larger institutional level, beyond the self, the technical, the business, and the professional ones. Thorough and adequate training about their social responsibility and their contribution to SD should expose them to the imperatives of larger changes versus strict individual and organizational behaviours. Our view of CSR is definitely not a business-case one, often abstracted to the self-regulated strategic and virtuous practices. Moreover, we esteem that adequately-trained ethical and responsible managers are aware of the dilemmas they will be facing as they exercise the managerial profession and able to view SD as a collective and negotiated project in which social progress is the aim, economy is the means, and ecology and fairness are the requisites (Gendron and Reveret 2000).

19.2 The Engineers' Interest in Management Training and the Business Schools' Offerings

Proficiency in Management has been recognized as an added value to engineers' training, since the first teaching of Management courses in industrial engineering and system engineering departments took place at the beginning of twentieth century (Kocaoglu and Cleland 1981; Farr and Bued 2003; Kotnour and Farr 2005; Kocaoglu 2009). Later, as more major corporations hiring engineers expected them not only to design cost-effective technical and engineered systems but also to manage them in order to induce a favourable strategic position in the industry, the engineering-management (EM) education has come to be considered as a source of competitive advantage in the job market for engineers (Kocaoglu 1989; Omurtag 2009). In the highly-ranked business schools,[2] more than one third of full-time MBA students have an undergraduate degree in science and engineering (for example, for the entering classes of 2017 at Harvard Business School, CEIBS in China, and Stanford University Graduate School of Business, the proportions are respectively 36%, 51% and 39%. For 2016, it accounts for 38% at INSEAD in France, Singapore, and Abu Dhabi).[3] Management schools have seized that opportunity by offering EM-type programs. During the last 10 years, concentrations within master programs (MBA and MS),[4] hybrid programs offering dual or joint degrees with

[2] Top business schools according to rankings such as those of the *Financial Times*, *Bloomberg/BusinessWeek*, *The Economist*, and *Forbes*.

[3] According to the publicly available data found on the respective website of each school.

[4] For example, concentrations in the MS in Management Studies at the MIT's Sloan School of Management include: technology-based entrepreneurship and product development. At UCLA's Anderson School of Management, among the MBA specializations are: technology leadership and healthcare management. SDA Bocconi in Italy offers specializations in innovation management, food and beverage, and healthcare.

other schools,[5] and elective courses in science and engineering[6] areas have been breeding rapidly.

Before assessing to what extent business schools course and program offerings could respond to the need for CSR education of future engineer-managers, it is important to trace how the questions of ethics, CSR, and SD have emerged in the enginereering field in general and developed in the engineering-management field in particular. These developments explain the demand for adequate ethics, CSR, and SD education.

19.3 The Demand for Ethics, CSR, and SD Education in Engineering-Management

Our review of the main texts (for example, Frantz 1988; Davies 1995; Clarke and Rhodes 2002; Geistauts et al. 2008; Fenner and Jeffrey 2011; DiLoreto 2012), monographs, and textbooks (for example, Layton 1971; Gunn and Vesilind 1986; Florman 1987; Johnson 1991; Davis 1998; Fleddermann 2004; Martin and Schinzinger 2005; Harris et al. 2009) on ethical engineering, social responsibility of engineers, and sustainable engineering, as well as of others' reviews and critiques (for example, Baum and Flores 1978; Peterson 1996; Cavana and Mares 2004; Adamowski 2012; Basart and Serra 2013) have allowed us to stipulate that while engineer professionals and academics have adhered to broad extra-technical and social principles (far beyond self-interest, loyalty to the employing businesses, and professional interest), the mainstream ethical training provided to engineers mainly circumscribe ethics within the personal obligation toward the profession. In a similar manner, the SD education they receive has long been limited in scope, putting strictly an over-focus on the techno-ecological easily-measurable dimensions. The latter generally serve the "business-case" for the CSR of companies in general, including those hiring engineers. According to Archie B. Carroll and Kareem M. Shabana, business-case:

> refers to the arguments or rationales supporting or documenting why the business community should accept and advance the CSR 'cause'. The business case is concerned with the primary question: What do the business community and organizations get out of CSR; that

[5] For example, the Kellogg School of Management offers a dual degree (MBA and MMM) with McCormick School of Engineering. Stanford University Graduate School of Business offers joint degrees (MBA and MS) with the Computer Science Department and the Electrical Engineering Department. Columbia Business School has dual degrees (MBA and MS) with the Fu Foundation School of Engineering and Applied Science. Oxford University's Said Business School offers dual degrees (MBA and Msc) with the School of Geography & the Environment, Oxford Internet Institute, and the Department of Computer Science.

[6] For example, areas of elective MBA courses at Berkeley's Haas Business School include: energy and clean technology, health, and technology. At INSEAD in France, they include technology and operation management. INSEAD in Singapore offers elective courses in technology and operation.

> is, how do they benefit tangibly from engaging in CSR policies, activities and practices? For most, the business case refers to the bottom-line reasons for businesses pursuing CSR strategies and policies. (Carroll and Shabana 2010, p. 86)

Debates about engineering ethics can be traced back as early as the end of the nineteenth century, where many stakeholders formally reacted to major safety risks and design defaults related to engineered systems. As pointed out by the historian of technology Edwin T. Layton, engineering ethics questions arose following those hazards. The public's raising concerns and loss of confidence pushed the engineering practitioners' community toward a renewed intellectual quest in order for the profession to regain its legitimacy and to make engineers' work more socially responsible and trustworthy. On the academic's side, according to Christelle Didier (2008) theses engineering ethics developed within the field of philosophy of technology. Here Carl Mitcham's, and others' work in Science and Technology Studies (STS) contributed to the rapid development of engineering ethics as a scientific field. Technology could not be considered as neutral anymore. It can be said that both professionals and researchers belonging to the engineering and technology community have been reflective about engineers' protection of the public interest for quite a while.

More recently, issues arising in branches and their subfields brought about the development of applied engineering ethics covering particular areas and specialties (for example, genetic engineering, nanoscience, robotics, etc.). Despite intense philosophising about engineers' ethics and social responsibility, and the occurence of several incidents during the twentieth and twenty-first centuries (for example, water contamination, bridge and building collapses, chemical leaks, space shuttle disasters, etc.), ethical training provided to engineers still stresses the latters' duties to their profession. Yet professional associations, through their ethical codes, and engineer scholars continue to believe that engineers should put the public interest above all other competing interests (self, business, and professional). The mainstream social responsibility education to which engineers are exposed naively assumes that business interests, professional interests, and the public interests are compatible. Questioning that technology is neutral has not attracted much interest in the curriculum. The latter's propositions to students have remained technically, organizationally, and professionally-focused, although most of the issues at stake are institutional and systemic in nature. This approach has often translated teaching into preaching (Pfatteicher 2001). The assumption that individual values and due regard to the professional codes can guarantee ethical behaviour seems to have taken hold among engineering ethics' teachers. However, as Joseph Basart and Serra (2013) have reminded us, the engineer's ethics is just a part of a whole that must be considered when talking about engineering ethics; and professional codes of ethics do not cover the whole set of actors and systems involved in the world of engineering. There seems to be a need for a broader approach as highly complex CSR and SD challenges are relevant concerns calling upon the attention and interest of the engineering field.

Have the ideas of broader CSR and SD, beyond professional ethics and narrowly defined "business-and-professional-cases", brought the needed turn (more than the engineers' loyalty to their business and professional affiliations and beyond technical solutions[7]) into the definition of engineering ethics' educational domain? Furthermore, has the ambition of CSR, which should encompass an inquisitive approach to businesses' institutional framework, been understood by future engineer-managers (beyond the plea for the the individual responsibility of managers and the push for a market for virtue)? The engineering field has talked even more about CSR and SD since the mid-1990s as research funding, new publications (including specialized journals such as *International Journal for Sustainable Engineering*, *Journal of Engineering for Sustainable Development: Energy, Environment, and Health*, *Sustainability Science and Engineering* and special issues in EM publications such as the *Journal of Management in Engineering* in January 2012), conferences (for example, those of the Engineering Education for Sustainable Development), as well as new courses and programs on those subjects have increased.

On the practitioners' side, public policy makers, industries, and professional associations have responded essentially in two ways, as noted by Jan Adamowski (2012): (1) policy statements acknowledging the magnitude of the problems in addition to a pledge to steer engineering toward a more sustainable future, and (2) a plea for technological innovations. Moreover, the need for a broader education has been asserted. Professional associations have firmly stated that engineers have a unique role in society and in SD, and have developed educational programs that embed the principles of sustainability into credentials (DiLoreto 2012). But to the question whether the current educational priorities encompass the broader challenges, the answer is not necessarily affirmative (Fenner and Jeffrey 2011, Adamowski, ibid.). The education related to the field of engineering and SD, for example, has tended still to focus more on techno-environmental considerations[8] than on the human, political, and socio-economics ones. Richard A. Fenner and Paul Jeffrey noted that there is still a need to draw on a body of material which would focus on the relationship between engineering and human communities served by engineered systems and subjected to the risks they bear. According to Adamowski, extending the domain of engineering ethics and adopting a more holistic approach coherent with the notion of sustainable development means that engineers ought to be more actively engaged in political, technical, economic, and social discussions and processes – which currently doesn't seem to be the case. Training them to undertake that task is thus among what is expected from contemporary engineering educators.

[7] Depleting resources, climate change, and pollution are without discussion problems that the idea of sustainable development, and its operationalization are expected to tackle. Nonetheless, and this is what is often forgotten, issues related to social justice, human rights, and quality of life for both the current and the future generations are also among the issues expected to be addressed when talking about sustainable development.

[8] Such as "environmental stewardship practices and policies involving energy efficiency, water conservation, climate change, renewable portfolio standards, and other issues" (Qingbin and Fang, 2012).

Beyond considerations at the professional level, the need to highlight other levels of the relationships between engineering and society as well as between business and society is paramount when teaching engineer-managers (Davis 1998; Clarke and Rhodes 2002; Geistauts et al. 2008; Basart and Serra, ibid.). When working for a business, scientists and engineers already face difficult dilemmas balancing their social responsibility against the loyalty to their businesses. This kind of dilemmas is epitomized in whistleblowing. This is also what professional associations envisioned when they crafted their ethical codes. Thus, it is highly probable that when engineers become managers, they will be exposed to both dilemmas and trilemmas, and even quadrilemmas in terms of balancing self interest, fiduciary duty, professional interest, and public interest. Moreover, the managerial practice and decision making of engineer-managers take place within technical and organizational systems which themselves are embedded in complex social, political, cultural, and economic frames. George Geistauts et al. (ibid.) assert, for example, that their individual values, even when coupled with those expressed in their codes of professional conduct, are insufficient to guarantee that they would display a socially acceptable behaviour in every setting. When one looks at the industries that hire engineer-managers, one can easily notice that many issues (for example, drug pricing in developing countries, risks of corruption in the construction industry, risks associated with genetically-modified organisms and nanotechnology, privacy protection in the IT sector, product safety in the FMCG (fast-moving consumer good) sector, transfer pricing in the digital industry, planned obsolescence, etc.) are so problematic at the institutional level, that the mere competency (utilitarian) and ethical conduct (normative) of the engineer-managers are not enough to address them. It is not exaggerated to say that the agenda to educate engineer-managers about CSR will remain unfulfilled without a reflective inquiry. Many educators are aware of the urgency to radically transform engineers' ethical training. Samuel Florman (ibid.) contended, for example, that in order for engineering students to escape from the current ethical narrow outlook, a broader education in liberal arts is needed. The next section will deal with the following question: How far have MBA programs gone into ethics, CSR and SD teaching to future managers, more than a third of whom are engineers and scientists?

19.4 The "Unfulfilled Agenda" of Responsible Management Education in Business Schools

Increasing numbers of engineers are attending business schools offering specialized courses and programs for students having a background in science and engineering. Since these future engineer-managers are in need of a broader ethics, CSR, and SD education, it can be assumed that management educators are expected to have a role to play in such an endeavour. As we will argue in this section, this role needs to go beyond exposing students to the mainstream discourses – those of instrumental ethics, loyalty to businesses, and moral righteousness toward the profession. However, as we will demonstrate using recent data, such a challenge seems not to have been addressed so far. Hence future engineer-managers within the business schools setting have yet not found the broader, inquisitive, and reflexive ethics, CSR, and SD training their profession has long been demanding.

Texts about the teaching of CSR specifically to engineers and scientists pursuing business degrees are scarce. However, in recent years, ethics, CSR, and SD teaching in business schools has been the subject of intense criticisms. Critics (for example, (Moon and Orlitzky 2011; Springett and Kearins 2001; Bradbury 2003; Crane and Matten 2004; Ghoshal 2005 Lapointe and Gendron 2005; Springett 2005; Giacalone and Thompson 2006; Evans et al. 2006; Waddock 2007; Hartman and Werhane 2009; Petrick et al. 2011; Wright and Bennett 2011; Cornuel and Hommel 2015; Doherty et al. 2015; Dyllick 2015) assert that rather than stimulating reflexive thinking, the mainstream approach is largely designed to serve the new "market for virtue" (Vogel 2005). As a result what is mainly taught is either the demonstration of the positive link between more extra-financial-issue-aware managers and more profits or the positive link between more ethic-sensitive managers and more pragmatic legitimacy (better reputation or less corporate scandals). Business schools have tended to offer courses that are over-focused on instrumental (theoretical recipes for success), strategic (tools for cost-effective social and environmental issue management), or normative (moral righteousness or rectitude toward stakeholders) perspectives. However, instrumental and normative perspectives of CSR draw directly from the technical and instrumental image of the organization. Training in management is providing a tacit stamp of approval for the current corporate and institutional framework, according to those critics. However this is basically the same framework in which severe social disparities, natural resource depletion, and economic crises have occurred. As Joseph A., Wesley Cragg, and Martha Sanudo noted:

> Themes in (…) business ethics largely indicate an acceptance of the status quo business context and preparation to adjust to and operate within that status quo. There is limited critical analysis or morally imaginative constructive posing of alternative macro and moral standards. (Petrick et al. ibid., p. 58)

The cost of CSR is not discussed, as the business-case seems to be the only legitimate and dominant discourse. Are the critics' points still holding true?

From our recent empirical assessment of ethics, CSR, and SD teaching in major business schools around the world (see Ramboarisata 2016), we found they are. The need for a broadening of ethics, CSR, and SD teaching beyond the "business-case" approach has remained unmet. That seems to echo Eric Cornuel and Ulrich Hommel's statement that responsible management education is an "unfulfilled agenda" (Cornuel and Hommel ibid.).

Our empirical study's sample was composed of the 121 business schools found on the 2015 edition of the magazine *Corporate Knight*'s "Better World MBA" ranking.[9] As regards the integration of ethics, CSR, and SD teaching into the MBA

[9] Corporate Knight scores world business schools (mainly those from the *Financial Times* MBA ranking) according to their performance in research (as measured by the number of research centers, the number of publications, and the latter's number of citations) in the field of ethics, CSR,

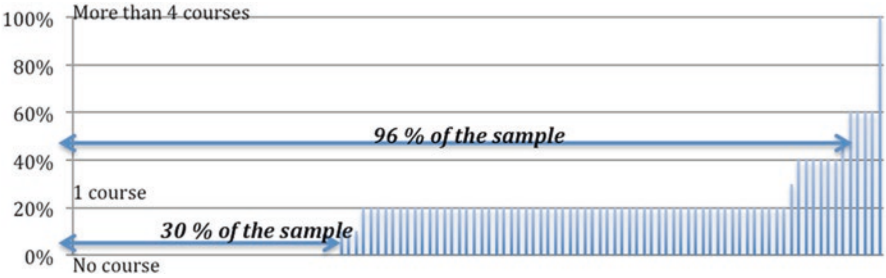

Fig. 19.1 Assessment of ethics, CSR, and SD courses' integration into the MBA offerings of major business schools in 2015 (score out of 100%, n = 121 schools)

curriculum, the current situation is portrayed in Fig. 19.1. The average score being extremely low (17 out of 100) which is indicative of a non-significant integration. One sole school obtained a score above 60. Only five schools (4%) got a score equal or superior to 50. Around one third of the sample (30%) was scored zero, which means that no ethics, CSR, and SD subject is taught in these schools' MBA programs. That underperformance concerns all regions. Prior studies, which noticed a significant exposure of business students to ethics teaching, were focused on the undergraduate curricula in the North-America.

A thematic analysis, using categories identified in prior work (Rossouw 2002; Lapointe and Gendron 2005; Waddock ibid.; Raufflet and Mena 2012; Raufflet and Schmitt 2015), has allowed us to map the foci of the existing 93 stand-alone courses (Fig. 19.2).

A first group of courses aiming at presenting business-case theories and providing students with the cognitive skills to apply them to real life business situations (mostly multinational corporations) accounts for 33.5% of the sample. More advanced courses, representing 42% of the sample, include the same objectives as those of the first group, but also target competencies for the implementation of programs (for example, certifications, reporting assurance, etc.) in specific industries (for example, maritime, mining) or context (for example, regional, international, third-world, indigenous territory) as well as domain-specific programs (for example, sustainable value chain, health and safety). Those two groups, representing a significant majority of 75.5%, favour discourses of ethical leadership (moral righteousness), instrumental issue-and-stakeholder-management, and the lucrative and legitimacy advantages of ethics, CSR, and SD.

A third group, of only 6.5% of the sample, focuses on the idiosyncratic challenges and social innovations or eco-innovations of other types of organizing (nonprofit, social entrepreneur, social enterprise, small venture, student's community-development project, etc.). Courses in this group mainly consist in con-

---

and SD, and performance in teaching at the MBA level (as measured by the number and relevance of compulsory stand-alone courses or the inclusion of those subjects in other compulsory courses).

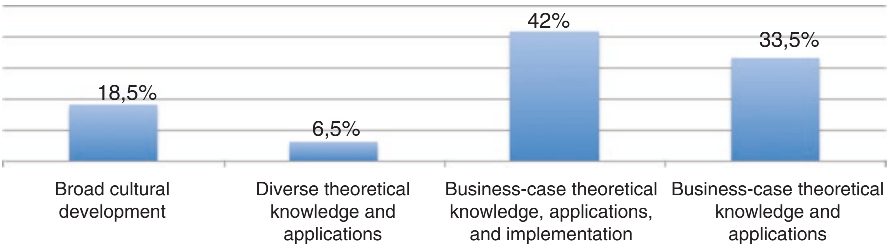

Fig. 19.2 Stand-alone courses' foci (objectives and approaches) at the MBA programs of major business schools (n = 93 courses)

sulting practicum, lab, and project. They include both theoretical and practical immersion in the context of those particular enterprises.

The remaining 18,5% of the sample is composed of courses the main objectives of which are to provide students with an overview of the historical, political, and economic roots and modern context of capitalism and businesses. Informed by multidisciplinary perspectives, they invite students into a critical and practical understanding of the significance of management in a contemporary and globalized setting. They also raise students' awareness about the assumptions of different theories of ethics, CSR, and SD. Practical coverage includes the principles of CSR, ethics, human rights, law, precaution, justice, stakeholder dialogue and legitimacy as they apply to organizations, domestically and abroad. Some expose students to the paradoxical realm in which managers are operating and the institutional status of businesses. As the targeted cultural development (literacy and behavioural awareness) is broad, competencies for program implementation are minimally covered.

From those findings, it can be asserted that no single course is currently meeting the ensemble of objectives identified in prior work as needed to fulfill the agenda of responsible management education. In other words, it does not seem feasible within one stand-alone course or the fraction of a mainstream course:

- To expose students to plural theories (beyond those of the business-case),
- To develop skills needed for a sound application of the theories in real business setting,
- To provide students with tools to understand and manage issues as well as to implement programs,
- To raise students' awareness about the particular challenges of other forms of organizing (cooperative, non-profit, social enterprise, benefit corporations, eco-innovation venture, etc.),
- To invite students into a reflective inquiry about the institutional framing of businesses' discourses and practices.

Such a comprehensive endeavour seems only possible when students are exposed to more than one stand-alone CSR course in the same school or are allowed to take elective ethics and SD courses in other departments or faculties. Only 5 schools out of the 121 under examination are currently pursuing that choice. It can thus be said that the promise of exposing engineering-management students to alternative narratives about business ethics as well as broader CSR and SD views has not been fulfilled, although such a demand has been expressed by the engineering-management community itself. No significant critical-pragmatic turn, aknowledging among other things the extreme dilemmas managers face in their decision-making processes and the social construction of technical work, have been noted so far in the MBA programs.

19.5 A Contribution to the Pragmatic-Critical Turn: Our Experience Based on the Premises of the *École de Montréal*

Despite the seemingly business-case (utilitarian and normative) emphasis found in current ethics, CSR, and SD teaching, a pragmatic-critical turn has found interest among some business educators (e.g., Springett and Kearins 2001; Bradbury 2003; Kearins and Springett 2003; Welsh and Murray 2003; Brown and Macy 2004; Lapointe and Gendron 2005; Springett 2005; Giacalone and Thompson 2006; Waddock 2007; Hartman and Werhane 2009; Von der Heidt and Lamberton 2011). It

> promotes a sense of both local and global responsibility, encourages future-oriented and critical thinking … dealing with all three realms of sustainability – environment, society, and economy, being interdisciplinary … and promoting participatory learning and higher-order thinking skills… Underpinned by the principles of critical theory and critical thinking skills, … aims to go beyond individual behaviour change. (Von der Heidt and Lamberton ibid., pp.672–673)

Consequently, it insists on the relevance of a reflective inquiry toward the larger institutional level, beyond the business and the professional ones. It suggests that the instructors ask "big" questions that business scholars and students are not used to.[10] For future engineers pursuing a business degree, to become reflective practitioners entails that they ought to be educated about the interactions between engineered and non-engineered systems, the relations between the organizations they work for and society, as well as the values and views of the different actors in such interactions, the social structuration of their practice for example, the spread of

[10] As the president of the Academy of Management stated in the call for contributions for the 2013 Academy's annual conference, the theme of which was "Capitalism in question", "The recent economic and financial crises, austerity, and unemployment, and the emergence of many economic, social, and environmental protest movements around the world have put back on the agenda some big questions about this vision: What kind of economic system would this better world be built on? Would it be a capitalist one? If so, what kind of capitalism? If not, what are the alternatives? Although most of our work does not usually ask such "big" questions, the assumptions we make about the corresponding answers deeply influence our research, teaching, and service (Academy of Management 2013 Meeting, http://aom.org/annualmeeting/theme/#call, accessed 24 February, 2013).

some engineering-management models throughout the world and their impacts on different communities, the conditions under which solutions to social and environmental issues (for examples, norms and standards) are negotiated and agreed on, etc. (Russell 2001, Adamowski ibid.).

Taking our instructional experience as illustrative of an adhesion to that pragmatic-critical turn, below we provide an account of how we defined the aim and scope of the stand-alone course we are teaching at the graduate level. Our course, titled "*Contexte économique et socio-politique*" (Economic and socio-political context) is a mandatory part of both the specialized MBA in Science and Engineering and the E-MBA in Technology Management at the business school of the University of Québec in Montreal (ESG-UQAM). Our approach is founded on the premises of *the École de Montréal* (Montreal CSR School), a socio-critical perspective, at the junction of the Canadian and the European CSR scholarships.

Settled on and evolving in a dual tradition (linguistic, cultural, intellectual, economic, political), Montreal has been the birthplace of a number of original perspectives in social sciences. As regards CSR as a scientific object, the community gathered within and around what is now known as the *École de Montréal* (Gendron and Girard 2013) provides a unique hybrid perspective. It appraises the combining of institutional regulatory framework and local social innovations; state coercion, market incentives, and social movement mechanisms; managerial approach and political debate; as well as academic and classical readings of economic, political, sociological, and philosophical thoughts. As a "school", that of Montreal is distinct from others by the novelty of the CSR problematizing and conceptualization it suggests mainly because of its attempt to bridge insights from the two sides of the Atlantic, the continuity through its identification to founding authors, and the scope of its field of analysis. Despite the diversity of their background (law, economics, management, sociology, political sciences, accounting, environmental sciences, anthropology, engineering), members of the *École de Montréal* share the conviction that the debate about CSR should not be dissociated from that of the regulation challenges in a context of globalization. Although the idea had germinated at ESG-UQAM, the *École*'s members include scholars from other universities in Canada as well as many others from Europe. Among the school's premises, which have highly impacted the research and teaching of the members, are those on the role of a business corporation, on ethics, on CSR, and on SD (Table 19.1).

According to those premises, although it is important to learn how businesses can change their technical and managerial practices, it is also essential to understand their institutional framing and status. Hence, responsible management education must not be limited to promoting the discourse and practice of self-regulated CSR (Gendron et al. 2004). It must do more than provide an individual education in ethics and introduce students to debates regarding the ethical aspects of management and corporations. Management students must receive an education that allows them to recognize corporations as social institutions, so that they can gauge their impact on a social scale and better weigh the values that inform them. Contrary to the dominant approach in North America, ours is based on the view that the organizational and structural factors weighing on managerial decisions (business finality

Table 19.1 Premises of the *École de Montréal*

Business corporation	A private social institution that cannot be reduced to its individual component actor; an instrument of production, innovation, power, and social structuration (Touraine 1969)
Ethics	A questioning of the political-economic institutions that shape the dominant organizing and governance modes, cannot be reduced to the manager's behavioural-ethics, moral righteousness, and professional code of conduct
CSR	A set of discourses and practices regarding the role of business in society, cannot be solely founded on the postulate of self-regulation (which has eclipsed calls to fundamentally redefine the role of business in society) (Gendron et al. 2004)
SD	A collective and negotiated project in which social progress is the aim, economy is the means, and ecology and fairness are the requisites (Gendron and Reveret 2000)

of maximum value, performance evaluation criteria, peer pressure) are so heavy that even the most ethical managers are not necessarily going to make their businesses more socially responsible. Therefore, we believe that ethical issues must be contextualized within the institutional framework that influences and legitimates managers' conduct. To this end, we believe that students must develop an understanding that, as a private social institution (Touraine 1969), a corporation is not only an instrument of production but also an instrument of power and social structuration. First and foremost, by virtue of its legal status, it must serve the needs of shareholders as had already been suggested by Adolf Berle and Gardiner Means (1932). Therefore, managing a company cannot be a purely pragmatic, neutral and non-ideological activity (De Gaulejac 2005). It is based on a vision of the world in which humankind (and the environment) is a resource that serves the business and in which high-performance management maximizes the value to shareholders, by externalizing costs. The *École de Montréal* recognizes, however, that social innovations as well as ethical tensions can be found in other forms of enterprises (for example, cooperatives, non-profit, etc.).

Students enrolled in both programs in which our course is taught have undergraduate degrees in mechanical engineering, chemical engineering, civil engineering, computer science, biology, health science, and fundamental sciences. In the chronology of both MBAs' curricula (generally five terms), our course is at a late stage (during the fourth term). In the prior terms, students attend courses in human resources, marketing, finance, and production. Hence, we can afford not to emphasize the development of problem-solving skills, which are already acquired during earlier terms. Instead, we choose to target their theoretical literacy, application know-how, communication skills, competencies in collective deliberation, critical thinking, research skills, and creativity (Table 19.2). The syllabus clearly states that

Table 19.2 Aim and scope of our stand-alone ethics, CSR, and SD course taught at the MBA level

Objectives	Approaches	Sample activities
Multidisciplinary theoritical literacy	Learning to identify a theory's underlying assumptions, the common and the divergent theoretical explanations of the same object or phenomenon (business objectives, value creation, CSR, performance, etc.) Understanding why some theories and their toolkits have historically gained more importance than others	Readings and in-class lectures
		Documentary-watching
		Web-TV lectures or authors' interviews (for example, xerficanal-economie.com, tvdma.org)
		Theatre presentations of society (history of capitalism and corporations)
		3-page reflexions drawn from readings (by students)
Application know-how	Using theoretical lenses, learning:	In-class short presentation about the topic of the day (by a team of two students)
	To articulate theories with "real" business situations (naming, illustrating, mapping)	In-class discussion of news and events (for example, adoption of "Google tax" regulations in different countries, US presidential veto against Keystone XL, Rockefeller family charity's withdrawal from investments in fossil fuels, government approval of GMO salmon sale in US and Canada, shale gas drilling in Europe, etc.)
	To assess a situation (identifying actors involved and their interests/assumptions)	Case analysis
		Individual exam
		Team exercise (for example, issue and stakeholder analysis)
Communication skills	Building a well-informed opinion	Final project (a presentation and a written report)
	Communicating thought process to others	Simulation and role-playing (parliamentary commission examining a new technology regulation)
	Learning to listen and to take notes	Team exercise
	Building on others' positions	In-class participation
	Orally delivering presentations	

(continued)

Table 19.2 (continued)

Objectives	Approaches	Sample activities
Competencies in collective work (deliberation, decision-making, consensus building, project-making)	Team building	
	Developing collaborative skills (respect of common objectives and deadlines, using technology for team work)	
	Learning to make time for a cohesive integration of the different members' contributions *versus* strictly adding them up (This also helps the team to verify if a member has committed plagiarism)	
Research skills and creativity	Learning to identify trustworthy and objective sources	Individual exam
	Learning to do bibliographical search	Final project
	Learning to organize and synthetize information	Case analysis
	Creative use of technology and media	
Critical thinking	Critical assessment of decisions/choices at various levels	Reflexive journal
	Critical assessment of theoretical assumptions	Blogging
	Controversy analysis	Final project
	Learning to recognize a paradox	Individual exam
	Being aware of some conflictual rationales of individual managers, businesses, professions, and society	

the course's main objective is to advance students' understanding of ethics, CSR, and SD through an examination of institutional frames and features of businesses' policies and practices, the values that inform them, as well as the particular dilemmas and paradoxes scientists, technology experts, and engineers holding management positions are exposed to (*versus* a search for these concepts' normative and universal definitions or for the "best ways" to implement them in organizations or for the best substantive and procedural parameters of social and environmental performances). The early part of each 6-h-class[11] is devoted to laying out a comprehensive, detailed conceptual framework using insights from various theoretical and disciplinary lenses (including Management, Political Economy, Philosophy, and Sociology of organizations). In-class applications follow. Though not without difficulties, the theoretical readings used for the first part of each class encourage future engineer-managers to make sense of the interactions between their organizational or project setting and the broader socio-economic system beyond a mere utilitarian and normative understanding. The various applicative, developmental, and reflective activities that follow give them the opportunity to actively participate in the learning process and to make use of their knowledge of their sectors' specific issues, stakeholders, and realities.

[11] A term includes a total of five classes. Each six-hour-class is given on a weekend day.

We are aware of the fact that the theoretical part, drawn from critical multidisciplinary perspectives, is not an effective “hook” for MBA students whose perception of a course’s relevance may still be entrenched in the mainstream rationale of business-case or bottom-line. However, our pedagogical choices (small group activities, in-class discussions, creative projects, journal writing, case analysis, simulation, technology and media use) have allowed us to increase learning, retention, and most importantly, students’ interest. Students’ appreciation and their feeling that their becoming reflective practitioners is relevant to their work and social development, as expressed in the teaching evaluation and in their reflexive journals, are rewarding.

19.6 Conclusion

The main objective of our chapter was to discuss whether and how business schools could respond to the challenge of educating future engineer-managers about ethics, corporate social responsibility, and sustainable development, as engineers and other scientists represent an important proportion of business graduate students. Observations of the trajectory of the demand for both responsible engineering education and responsible management education, as well as reviews of earlier works on these themes, allowed us to assert that a critical turn is imperative. Such a turn has not yet gained the interest of many educators though, according to recent critics of CSR teaching in business schools and our own empirical study of the integration of responsible management training at the MBA level. Relying on others’ propositions and our own teaching experience, we explain that however challenging it might be, the adoption of a pragmatic-critical approach is feasible. Overall, the goal is to apply a diversity of teaching strategies to enhance the feelings of relevancy and engage students with overarching critical concepts.

References

Adamowski, J. (2012). Operationalizing sustainability principles in the engineering profession. *Natural Resources, 3*(4), 180–183.

Basart, J. M., & Serra, M. (2013). Engineering ethics beyond engineers ethics. *Science and Engineering Ethics, 19*(1), 179–187.

Baum, R. J., & Flores, A. (1978). *Ethical problems in engineering, center for the study of the human dimensions of science and technology* (p. 335). Troy: Rensellaer Polytechnic Institute.

Berle A., & Means G. (1932). *The modern corporation and private property*. Transaction Publishers.

Bradbury, H. (2003). Sustaining our inner and outer worlds: A whole-systems approach to developing sustainable business practices in management. *Journal of Management Education, 27*, 172–187.

Brown, J., & Macy, J. (2004). Teaching sustainability: Whole-systems learning. In *C. Galea, teaching business sustainability*. Sheffield: Greenleaf.

Carroll, A. B., & Shabana, K. M. (2010). The business case for corporate social responsibility: A review of concepts, research and practice. *International Journal of Management Review, 12*(1), 85–105.

Cavana, R. Y., & Mares, E. D. (2004). Integrating critical thinking and systems thinking: From premises to causal loops. *System Dynamics Review, 20*(3), 223–235.

Clarke, S., & Rhodes. (2002). Managing engineering for a sustainable future. *Engineering Management Journal, 10*(6), 275–280.

Cornuel, E., & Hommel, U. (2015). Moving beyond the rhetoric of responsible management education. *Journal of Management Development, 34*(1), 2–15.

Crane, A., & Matten, D. (2004). Questioning the domain of the business ethics curriculum. *Journal of Business Ethics, 54*, 357–369.

Davies, P. W. F. (1995). Managing technology: Some ethical preliminaries. *Business Ethics, 4*(3), 130–130.

Davis, M. (1998). *Thinking like an engineer: Studies in the ethics of a profession*. Oxford University Press.

De Gaulejac, V. D. (2005). *La société malade de la gestion : idéologie gestionnaire, pouvoir managérial et harcèlement social*. Paris: Éditions du Seuil.

Didier, C. (2008). *Penser l'éthique des ingénieurs*. Paris: Presses universitaires de France.

DiLoreto, G. E. (2012). The sustainability edge. *Civil Engineering, 82*(12), 12.

Doherty, B., Meehan, J., & Richards, A. (2015). The business case and barriers for responsible management education in business schools. *Journal of Management Development, 34*(1), 34–60.

Dyllick, T. (2015). Responsible management education for a sustainable world: The challenges for business schools. *Journal of Management Development, 34*(1), 16–33.

Evans, J. M., Trevino, L. K., & Weaver, G. R. (2006). Who's in the ethics driver's seat? Factors influencing ethics in the MBA curriculum. *The Academy of Management Learning and Education, 5*, 278–293.

Farr, J. V., & Bued, D. M. (2003). Systems engineering and engineering management: Keys to the efficient development of products and services. *Engineering Management Journal, 15*(3), 3–9.

Fenner, R. A., & Jeffrey, P. (2011). Editorial: Addressing the human dimension in socio-technical systems. *Proceedings of the Institution of Civil Engineers: Engineering Sustainability, 164*, 1–3.

Fleddermann, C. (2004). *Engineering ethics*. Pearson Education.

Florman, S.C. (1987). *The civilized engineer*. St. Martin's Press, 258 p.

Frantz, L. R. (1988). Engineering ethics: The responsibility of the manager. *Engineering Management International, 4*(4), 267–272.

Geistauts, G., Baker, E., & Eschenbach, T. (2008). Engineering ethics: A system dynamics approach. *Engineering Management Journal, 20*(3), 21–28.

Gendron, C., & Reveret, J.-P. (2000). Le développement durable. *Économies et société, 37*, 111–124.

Gendron, C., & Girard, B. (2013). *Repenser la responsabilité sociale de l'entreprise* (p. 400). L'École de Montréal: Armand Colin.

Gendron, C., Lapointe, A., & Turcotte, M.-F. (2004). Responsabilité sociale et régulation de l'entreprise mondialisées. *Relations industrielles, 59*(1), 73–100.

Ghoshal, S. (2005). Bad management theories are destroying good management practices. *The Academy of Management Learning and Education, 4*(1), 75–91.

Giacalone, R. A., & Thompson, K. R. (2006). Business education and social responsibility education: Shifting the worldview. *The Academy of Management Learning and Education, 5*, 266–277.

Gunn, A.S., & Vesilind, P.A. (1986). Environmental ethics for engineers. Lewis Publishers, 153 p.

Harris, C.E., Pritchard, M.S., & Rabins, M.J. (2009). Engineering ethics: Concepts and cases. Wadsworth Publishing, 411 pp.

Hartman, L., & Werhane, P. (2009). A modular approach to business ethics integration: At the intersection of the stand-alone and the integrated approaches. *Journal of Business Ethics, 90*, 295–300.

Johnson, D. G. (1991). *Ethical issues in Engineering* (p. 392). Englewood Cliffs: Prentice-Hall.

Kearins, K., & Springett, D. (2003). Educating for sustainability: Developing critical skills. *Journal of Management Education, 27*, 188–204.

Kocaoglu, D. F. (1989). Strategic opportunities for engineering management. *Engineering Management Journal, 1*(1).

Kocaoglu, D. (2009). Engineering management-where it was, where it is now, where it is going. *Engineering Management Journal, 21*(3), 23–25.

Kocaoglu, D., & Cleland, D. I. 1981. *Engineering management*. McGraw-Hill Book Co.

Kotnour, T., & Farr, J. (2005). Engineering management: Past, present, and future. *Engineering Management Journal, 17*(1), 15–26.

Lapointe, A., & Gendron, C. (2005). Enseigner la RSE: de la recette utilitariste à la réflexion sur l'entreprise comme institution sociale privée. Cahier de la Chaire de responsabilité sociale et de développement durable, no 04-2005, 24p.

Layton, E.T. Jr. (1971). *The revolt of the engineers: Social responsibility and the American engineering profession*. Johns Hopkins University Press, 286 pp.

Martin, M., & Schinzinger, R. (2005). *Ethics in engineering*. McGraw-Hill Education, 339p.

Moon, J., & Orlitzky, M. (2011). Corporate social responsibility and sustainability education: A trans-Atlantic comparison. *Journal of Management & Organization, 17*(5), 583–603.

Omurtag, Y. (2009). Engineering management: Past, present and a brief look into the future for the EMJ founders. *Engineering Management Journal, 21*(3), 33–35.

Peterson, J. L. (1996). The new and old work ethic examined. *Engineering Management Journal, 8*(4), 15–19.

Petrick, J., Cragg, & Sanudo. (2011). Business ethics in North America: Trends and challenges. *Journal of Business Ethics, 104*, 51–62.

Pfatteicher, S. K. A. (2001). Teaching vs. preaching: EC2000 and the engineering ethics dilemma. *Journal of Engineering Education, 90*(1), 137–142.

Qingbin, C., & Fang, D. (2012). Introduction to the special issue of engineering management for sustainable development. *Journal of Management in Engineering, 28*(1), 1.

Ramboarisata, L. (2016). Des MBA responsables? Un éclairage institutionnaliste et discursif. Cahier du Centre OSE, no 03–2016, Université du Québec à Montréal. http://ose.esg.uqam.ca/wp-content/uploads/sites/13/2016/07/Cahier-de-recherche-3-Des-MBA-responsables-Un-éclairage-institutionnel-et-discursif.pdf.

Raufflet, E., & Mena, D. (2012). Revue de la littérature sur l'intégration du développement durable dans la formation en gestion. Cahier de recherche du GRID-HEC, no 2012–3.

Raufflet, E., & Schmitt, P. (2015). Sustainability in higher education: A systematic review with focus on management education. *Journal of Cleaner Production, 106*, 22–33.

Rossouw, G. J. (2002). Three approaches to teaching business ethics. *Teaching Business Ethics., 6*(4), 411–433.

Russell, B. (2001). *Sustainability issues*. Canadian DND publication. Special issue of engineering management for sustainable development. *Journal of Management in Engineering*, *28* (1).

Springett, D. (2005). Education for sustainability in the business studies curriculum: A call for a critical agenda. *Business Strategy and the Environment, 14*, 213–221.

Springett, D., & Kearins, K. (2001). Gaining legitimacy? Sustainable development in business school curricula. *Sustainable Development, 9*(4), 209–221.

Touraine, A. (1969). *La société post-industrielle*. Paris: Édition Denoël.

Vogel, D. (2005). *Market for virtue: The potential and limits of corporate social responsibility*. Washington, DC: Brookings Institution Press 222 p.

Von der Heidt, T., & Lamberton, G. (2011). Sustainability in the undergraduate and postgraduate business curriculum of a regional university : A critical perspective. *Journal of Management & Organization, 17*, 670–690.

Waddock, S. (2007). Leadership integrity in a fractured knowledge world. *The Academy of Management Learning and Education, 6*(4), 543–557.

Welsh, M. A., & Murray, D. L. (2003). The ecollaborative: Teaching sustainability through critical pedagogy. *Journal of Management Education, 27*, 220–235.

Wright, N. S., & Bennett, H. (2011). Business ethics, CSR, sustainability and the MBA. *Journal of Management & Organization, 17*(5), 641–655.

Lovasoa Ramboarisata Associate professor at the Department of Strategy, Social and Environmental responsibity at UQAMs School of Management Science (ESG). She teaches Management theories, Social & organizational Changes, CSR, and Economic & socio-political context at the B.B.A. and M.B.A levels. She is member of OSE (Organizations, Societies, and the Environment) Research Center and of the Research Chair in Social Responsibility and Sustainable Development. She sits on the board of the International Research Network on Organizations and Sustainable Development (RIODD). She has published papers in peer-reviewed management journals, book chapters, and reports in the fields of CSR, governance, cooperative organizations' management, entrepreneurial university, and business education.

Corinne Gendron Lawyer, MBA and PhD in economic sociology, professor at UQAMs School of Management Science (ESG), and head of the research chair in Social Responsibility and Sustainable Development (CRSDD). Ms Gendron has published numerous articles on sustainable development, social responsibility and new regulations, as well as several books including *Regulation Theory and Sustainable Development*, Routledge (2012). In 2016 she received the Légion d'honneur from the governement of France, after becoming Academicienne at the Academie des technologies. Presently, she is president of the scientific comitees of INERIS and IFSTTAR, and member of the scientific comitee of ENGIE. She recently received the Prix de la recherche by UQAMs School of Management Science for her career.

Chapter 20
Engineering-Business: The Co-production of Institutions, Skills and Engineering Challenges

Joakim Juhl and Anders Buch

Abstract The long-lived and widely held political imagination surrounding innovation is that of a process by which new developments in science and technology are transformed into new business applications. As a result higher education and professions are eager to impose their expertises onto, and claim authority within, the domain of innovation. In recent decades, universities and other engineering institutions that are typically associated with technology development, or 'technology push', have expanded their research and teaching activities toward the business end of innovation – also known as the 'demand' or 'pull' side. The chapter investigates the new emergent trend in academic institution building where business or demand-oriented competencies are incorporated to engineering curricula. Drawing on the theoretical frameworks of co-production and sociotechnical imaginaries developed by Sheila Jasanoff and others, we analyze how social scientists at the Technical University of Denmark, in response to new demands for autonomous economy within Danish universities, invented the 'Design and Innovation' engineering program. Despite its controversial curricular composition, Design and Innovation entailed a revised status for engineering that brought together: creativity; social awareness; and product innovation. The successful implementation of Design & Innovation can be seen as a result of its unique capacity to bring together emphasis on application with new 'holistic' visions for higher education. The chapter contributes to contemporary discussions of transformations within the university system and implies that we should look more closely at the interplay between engineering, business and the surrounding society, and how engineering and business are valued, in order to understand the meaning of the engineering-business nexus.

J. Juhl (✉)
Department of Planning, Aalborg University Copenhagen, Copenhagen, SV, Denmark
e-mail: Jjuh@plan.aau.dk

A. Buch
Department of Philosophy and Learning, Aalborg University Copenhagen, Copenhagen, SV, Denmark
e-mail: buch@learning.aau.dk

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_20

Keywords Engineering education · Higher education · Reform · Innovation · Sociotechnical imaginaries · Co-production

20.1 Introduction

In this chapter we interpret 'engineering-business' as a nexus within which epistemological, ontological and political boundaries between *engineering* and *business* are negotiated as part of changing social expectations of knowledge production. For the investigation of the changing social orders responsible for the repositioning of engineering in relation to business, we make the case that engineering education, its curricular content and institutional setup, is an important site for engineering-business scholarship. As a nexus, engineering-business combines 'engineering' – the domain that develop technologies by 'applying' science and mathematics to practical problems, and 'business' – the domain that translates technology into market applications. In the context of many new types of academic educational programs that target inter-disciplinary challenges between technology development and business application, we use an engineering-business curricular composition as an epistemic probe for understanding the sociopolitical context within which contemporary higher education and expert knowledge is ascribed meaning and value.

The engineering-business nexus represents a response to prevailing perceptions of the challenges facing engineering and engineering education (Buch 2012). In many western countries governments, industry, academia, and the engineering profession worry that what we generally conceive of as "engineering", is, in itself, not capable of tackling future challenges. Although opinions differ when it comes to specifying the nature of the challenges, there is general agreement about the need for taking steps to reform engineering education. Proponents from industry and governments have suggested that in order to remain competitive on a national, organizational, and individual level, engineers must be more 'business oriented'. Accordingly, the strategy is to allocate a substantial part of engineering curriculum to commercial topics. Concerned voices within academia have responded characteristically different by describing challenges to engineering education in terms of disintegration and proliferation of technological knowledge in modern society. Their suggested response strategy centers on visions for engineering practice to become more reflective, holistic, and innovative. Here engineering is seen as a socio-technical endeavor that fuses technical disciplines and social science disciplines into a mix that fosters 'a hybrid imagination' (cf. Jamison et al. 2011). Within this vision, engineers' abilities to design new products and be innovative are crucial.

Our empirical focus is on how a new form of engineering education called *Design & Innovation* came into being. It combines traditional engineering skills centering on 'technological problem solving' with holistic approaches to 'user-centered' problem definition (cf. Juhl and Lindegaard 2013; Buch 2016; Petersen and Buch 2016). The case illustrates how an overarching tendency to deploy 'innovation' as *the* universal success-criterion has expanded the notion of 'engineering' within higher education to include expertise and responsibilities that used to reside in business programs. The analysis presents an exemplary case for discussing the nexus of engineering-business as an institutionalizing formation within a changing normative space for higher education.

In order to give meaning to the term "engineering-business" we need first to look at the phrase's two distinctive parts. Both 'engineering' and 'business' need some form of clarification each in their own right – and what they mean in relation to one another. What makes the combination unique, interesting, and important for contemporary scholarship to investigate? While it is difficult to provide unambiguous definitions, we find it more productive to present a way of thinking about engineering and business that takes its outset in common ideas about their subject matters and the institutional settings in which each of them operate. Engineering is widely conceived of as the making of technology, or finding practical solutions to problems involving technology. Conversely, business can be understood to concern the exploitation of market opportunities whereby needs and demands are converted into economic transactions between the supply and demand sides of a market. The relationship between technological development and commercial application has perhaps become one of the most durable and long-standing pillars in modern culture and political thought – namely innovation.

In this chapter we investigate engineering-business as a form of innovation that entails two levels of meaning. The first meaning is that straightforwardly implied by the concept engineering-business, which centers on ideas about what it means to bring together competencies in technology development with skills in market application. The development of educational programs with new hybrid curricular offers us a view into what the combination of technological 'problem solving' skills with holistic 'demand assessment' competencies could look like. The other meaning refers to ideas about how to make more effective conditions for the transfer between technological development and market applications. Where the former is about the curricular *content,* that is imagined as relevant for making the transaction between technology and market, the later focuses on the institutional setup that underwrites this transaction. The emergence of the Design & Innovation program presents a case of how institutional dynamics around higher education undermined the preexisting system including its professional demarcations and necessitated researchers to redefine their professional identities in relation to their education contributions.

In order to grasp the implications of the Design & Innovation program we will first draw upon the recent theoretical development of sociotechnical imaginaries (Jasanoff and Kim 2009; Jasanoff 2015) as the interpretative framework before we turn to the early development of ideas about the relationship between technological development and economic progress. We need to investigate how these ideas have been transformed through their institutional makeup in order to support what at different times and places has been considered the rightful interaction between the two. In the following we account for the theoretical positions that enable us to read together the imaginary space of political culture with the trajectories of institutional developments and the framing of curricular content.

20.2 Sociotechnical Imaginaries: And the Fabrication of the Engineering-Business Nexus

Ideas about the nature, purpose, and value of human activities such as 'engineering' and 'business' are closely interwoven within our thoughts, practices and institutional forms. Not only have visionary philosophers, scientists, politicians and entrepreneurs theorized, dreamt and prophesized about the virtues of engineering achievements and the prosperity brought about by the development of new products and markets; the visions have also had a fundamental impact on the way we conceive of 'engineering' and 'business' as sociopolitical phenomena that are embodied within identities, social practices, and discourses.

In the tradition of Science and Technology Studies (STS) numerous studies have pointed to the social shaping of technology (cf. Mackenzie and Wajcman 1999). Determinist assumptions about technological change as an independent factor that impact society from outside society has been criticized and empirical studies have demonstrated how human interests, desires, and objectives are vital to understand technological innovation. Sheila Jasanoff has suggested that in understanding processes of social and technological change, the relationship between 'society' and 'technology' is a contingent and complex process of 'co-production'. Modes of knowing about and representing society and technology are inseparable from our social practices, identities, norms and institutional arrangements. Science and technology are both shaped by societal processes and constitutive of how we go about our businesses in social life (Jasanoff 2004, pp. 2–3). In this perspective we see 'engineering' and 'business' as complex bundles of practices that mobilize discipline specific knowledges and other cultural resources within institutional settings where they are ascribed authority and value. The institutional settings and the knowledge content being consumed are thus conceived of as inseparable and in a dynamic and mutually constitutive relationship with widely held expectations and visions of technologies and markets. The constitution of institutions of knowledge production and dissemination are thereby important markers of what in a society is seen as valuable and relevant to securing its future wealth and prosperity.

This nominal characterization of 'engineering' and 'business' however tells us little about the boundaries between 'engineering' and 'business'. In order to understand the dynamics and developments of the engineering-business nexus we need to delve into the complexities of the nexus of (institutionalized) practices as they unfold in specific local and contemporary contexts. We need to understand how visions about engineering professionalism and technological achievement are imagined in relation to desires of economic prosperity and growth in innovation. The notion of sociotechnical imaginaries originally developed by Sang-Hyun Kim and Sheila Jasanoff (Jasanoff and Kim 2009) helps us to understand how this link operates. Kim and Jasanoff define sociotechnical imaginaries as "…collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff 2015,

p. 4). Sociotechnical imaginaries are in other words assemblages of meanings and morally inflicted persuasions that inform and delimit actors' choices in life. Likewise, sociotechnical imaginaries are inscribed in material form as artifacts, tools, technologies and infrastructures that support the purposive objectives of intended practices. Sociotechnical imaginaries both stabilize, mediate, and are fueled by, moral convictions about good and evil, with cognitive perceptions of what is right or wrong, and practical considerations about desirability and undesirability to form overarching collective frameworks of intelligibility and value.

While co-production assumes a dynamical relationship between epistemic and normative developments, sociotechnical imaginaries account for how stabilities are attained and maintained in the means and ends with which we choose to reproduce society across space and time. Sociotechnical imaginaries thus inform our thinking on how social and technological innovation stabilizes around particular visions for technological and social progress and notions of preferred futures. Different and contradictory sociotechnical imaginaries can coexist, and the extent of their potency and political manifestation can vary at different times and in different societies. Paradigmatic shifts in political and technological orders are in this perspective explained by changing imaginaries (Anderson 1983). While it is generally recognized that different imaginaries coexist and compete for authority (Jasanoff 2015) within the normative space of political cultures, less is known about the dynamics of complementary imaginaries and how their combined presence affects political order.

The engineering-business nexus represents a collectively held vision of combining engineering and business competencies within new institutional constellations that were believed to provide more beneficial conditions for techno-economic innovation. In order to investigate the normative structures underpinning engineering and business respectively, sociotechnical imaginaries call for situated investigations of the widely held visions associated with their public construction processes and how they have manifested themselves in the ordering of (institutional) practices. Thus, investigating the sociotechnical imaginaries behind the emergence of the Design & Innovation program, calls for an account of how the prevailing imaginaries surrounding technology development and commercial application have changed. In the following we investigate how ideas about engineering/technology and business/markets have unfolded and impacted institutional settings.

20.3 Technology and Market Within the Postwar Social Order

The great focus on science and technology as engines for economic progress came as a consequence of the wartime efforts in military controlled research and development during WWII. The postwar definition of social purpose of science and technology was part of a mission to secure progress, wealth and prosperity that was thought within a two-dimensional technology-market dyad. Technology was the fruits of scientific breakthroughs and clever business entrepreneurs would ensure that market-mechanisms would harness new technological possibilities into new products and services for the benefit of society.

The policy innovation, successfully promoted by the distinguished MIT engineer and wartime hero, Vannevar Bush, and other collaborators of the famous 1945 report: *Science – The Endless Frontier*, was to continue public funding of science for the peaceful purposes of fostering technological innovation, economic growth, health and prosperity. The result, that many have since called 'the social contract' (Jasanoff 2011), entailed that the government would provide the necessary funding and agenda setting terms for science and in return the nation would receive a steady flow of technological inventions and technically trained personnel.

Bush's argument was that scientific progress was essential for progress in society:

> New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature […] This essential, new knowledge can be obtained only through basic scientific research." (p. 1) Bush recommendation was clear: "The Government should accept new responsibilities for promoting the flow of new scientific knowledge and development of scientific talent. (Bush 1945, chapter. 6, p. 1)

Contrary to the wartime efforts, where the government formulated clearly defined goals for the application of research, the new funding regime should instead promote research on scientists' own terms and leave its practical application to private industry.

On the other side of the Atlantic similar expectations of science emerged. In postwar Denmark the expectations were expressed on grounds that centered on practical application and value in the reconstruction of the Danish society. Already in 1940, plans had been drafted for the technical-scientific research council (TVF)[1] but the war postponed its realization to 1946. The new council attained resources from Denmark's national budget for "concrete research tasks" and managed Marshall-funding as well as other international funds for 'technical-scientific objectives'. Through the 1950s, Danish public planning focused on expanding the industrial sector, which meant that technical fields of research were given priority in order to reinforce the transition from agriculture to industry with technically trained labor.

But the government's investments in techno-scientific research did not suffice in the public eye. On February 2nd, 1951, approximately 10,000 students, professors and high-level administrators from the majority of Danish colleges joined together in front of the government building in the mutual demand for better conditions for higher education and research. Existing student scholarships and research grants from the private Carlsberg foundation had become increasingly insufficient and students and academics requested better public support. The public request resonated with the emergence of a new sphere for science policy, which in 1952 resulted in the founding of the state's normal science fund (SAF) and the youth's educational fund (UU).

---

[1] Det teknisk-videnskabelige forskningsråd. Source: http://www.statensnet.dk/pligtarkiv/fremvis.pl?vaerkid=807&reprid=0&filid=12&iarkiv=1

The youth's educational fund offered economic aid to all Danes who assumed education above the age of 18 and was the predecessor of the current Danish SU-system,[2] which was first formally established in 1970. The mission remained unchanged over the years: to compensate for social inequality by ensuring that "no skillful students would have to abandon higher education on the basis of absent economic possibilities."[3] The youth's educational fund marked the emergence of a widely held rationale and position within Danish political culture that regarded the promotion of social equality to be of primary importance.

Famously expressed at the 1960 election by the social democrat Viggo Kampmann, who won the election, the political climate of the late 50s and early 60s Denmark was characterized by an economic upturn and a growing public desire for social welfare:

> Now it goes up. The automatic increase in income means that taxes are flowing in. We know to seize this historical chance. These funds should not be paid back as tax cuts but [should] be used to get the population the goods that the majority desires. We want to build universities and colleges. We want to build social institutions. We want to support art and culture. We want to increase the standard within all areas. (Gaardmand 1993, p. 72)

20.4 Knowledge Production in the Neoliberal Age

The great expenditures of pursuing science's 'endless frontiers' gave rise to corresponding expectations of benefits in the public domain. In the United States, the place of origin for systematic public support of pure basic scientific research, the original sponsors of the social contract started to fear that the significant discoveries made in university laboratories were in danger of forever remaining locked away in academic ivory towers where they would not generate the promised benefits to society (Jasanoff 2011). Better incentives were needed in order to more effectively connect scientific discoveries with potential developers. The culmination came in 1980 when the U.S. Congress passed the Bayh-Dole Act that authorized federal grantees to patent results generated from public money.

As a result, the organization of scientific institutions as well as the social purpose by which science is politically justified has undergone dramatic transformation since the postwar era. While the paradox concealed within the rationale behind the original social contract entailed a discrepancy between public interest in return of investment and public support of a disinterested science, the Bayh-Dole Act introduced a new moral paradox: how can it be politically defensible to authorize private ownership of marketable discoveries resulting from federal funding?

Across western nations, a particularly strong relationship has developed between investments in research and the assessment of national and regional welfare. The percentage of gross domestic product (GDP) invested in research is now regularly

[2] "Uddannelses Støtte" translates into "Educational Support".

[3] Ref: https://da.wikipedia.org/wiki/Statens_Uddannelsesstøtte

used as a benchmark indicator for nations' capacity to innovate. On the economic front, the European Union has for more than two decades maintained a strong emphasis on increasing its investments in research in order to match the 3% of GDP observed in Japan and the US.[4] When Bush initially implemented the rationale that innovation depends on basic science, he and others' intentions were to safeguard public support for protecting science against political influence. Irony would have that the same rationale eventually developed into an argument for transforming science into a political instrument – the success of which was measured in economic growth.

European innovation analysts and policy advisors have proposed the advancement of public-private partnerships to signify a change in the underlying model for national innovation systems. Accordingly, Etzkowitz and Leydesdorff (2000) see society's increasingly 'knowledge based' nature to push a new mode of innovation that is organized around the so-called 'Triple Helix' model. Consequently, in this new order, universities – the knowledge producers – are understood to play an enhanced role over the previous pivotal role of the private firm (Lundvall 1988, 1992; Nelson 1993)[5] and the privileged role of the state (Sábato and Mackenzi 1982). Contrary to the 1960s American science policy ideal of a disinterested and apolitical science whose autonomy and integrity should be protected at all costs, the 1990s policy discussions turned their gravitas toward the most appropriate ways to regulate the purposes and processes of scientific knowledge production (Jasanoff 2011).

20.5 The Commercial Turn in Danish Academia

The commercial turn in Danish science came in 2001, when the then minister of science, technology and development, Helge Sander, launched the initiative, 'From research to receipt'. Since then, a steady stream of reforms have turned Danish universities into economically autonomous institutions and exchanged universities' collegial self-governing system of employee elected leaders with executive boards consisting primarily of external members from industry (Carney 2006). The 'bibliometric research indicator' – a Danish ranking system for international journals – became a counting system for measuring, comparing and distributing public funds between universities based on their publication scores (Bruun Jensen 2011). Another example was the instatement of 'recruitment panels' consisting of industry leaders whose advices and interests became part of Danish higher education's recurring accreditation.

[4] The Lisbon Strategy 2000–2001 An analysis and evaluation of the methods used and results achieved. Ref: http://www.europarl.europa.eu/document/activities/cont/201107/20110718ATT24270/20110718ATT24270EN.pdf

[5] Bengt-Åke Lundvall and Richard Nelson were among the main authors of the Lisbon Strategy.

In 2006 the Danish government further intensified its focus on "quality", "competition", and fewer but higher profile strategic long-term research projects. While steadily increasing Denmark's public investment in research from 0.8% to 1% of GDP from 2006 to 2010, an important component of the new game plan was to increase the share of competition distributed funds to reach more than 50% of the total public support for science no later than by 2010.[6] Whilst increasing competition, the complimentary part of the plan was to increase the share of private investment in research and development to become twice that of public investments. Decreasing funding for basic science and more funding for public-private partnerships meant that researchers had to make themselves attractive to industrial partners in order to secure funding. As a result, the success criteria for publicly funded research came to center increasingly on commercial application within industry for the most direct benefit to the Danish (Juhl 2016).

20.6 Changing Knowledge Boundaries

In the early 1990s European analysts of contemporary scientific conduct observed a tendency that broke with that of the Bush era's university based and disciplinary so called 'Mode 1' knowledge production. The new tendency that Michael Gibbons et al. (1994) termed 'Mode 2' knowledge production took place within its context of application rather than at universities and entailed a mix of approaches rather than one mono-disciplinary methodology. As a consequence, 'Mode 2's authors noted that the assessment method by which science was evaluated had to be reconsidered in order to encounter a new and more interwoven fabric of science that besides intellectual merit had to address questions about the purpose of its research, the marketability of its results, and the social accountability of its enterprise. In other words, a science that, in direct opposition to that imagined by Robert Merton, Vannevar Bush and Michael Polanyi, would be answerable to society rather than detached from it. The 'Mode 2' thesis reflects an imaginary of scientific knowledge production that was fundamentally transformed from that of Mode 1. Although Mode 2 expresses new forms of accountabilities on part of institutions of science and higher education that center on their impact within non-scientific domains, Mode 2 does not explain governance symptoms like the increased demand for transparency as attested by Marilyn Strathern (2000) within UK university systems and within the Danish university system by Stephen Carney (2006).

Mode 2 knowledge production characterized a historical paradigm shift away from disciplinary university based Mode 1 research where the overarching aim had been to acquire "reliable knowledge" about nature and society. Instead Mode 2 presented a shift towards "socially robust knowledge" that was produced by heterogeneous groups of actors and organized around the problem context to which

[6] Danmarks nationale reformprogram, Første fremskridtsrapport, Regeringen 2006.

their joint efforts applied. In the view of its authors the new mode of knowledge production included the following characteristics:

- Knowledge is increasingly produced in contexts of application (that is, *all* science is to some extent "applied" science)
- Science is increasingly trans-disciplinary; that is, it draws on and integrates empirical and theoretical elements from a variety of fields.
- Knowledge is generated in a wider variety of sites than ever before, not just universities and industry, but also in research centers, consultancies, and think tanks.
- Participants in science have grown more aware of the social implications and assumptions of their work (that is, they have become more "reflexive"), just as publics have grown more conscious of the ways in which science and technology affect their interests and values.[7]

Mode 2 science's values and ethos in other words became more akin to what we in this anthology refer to as 'engineering-business' where competencies of multiple origins came together in contexts of application around the mutual purpose of generating commercial impact. By making Mode 2 science's performance criteria about how knowledge production impacts society rather than how it adheres to scientific disciplines' internal criteria, Mode 2 brings into question disciplinary distinctions such as that between business and engineering. According to its authors, the Mode 2 version of expertise, "transdisciplinarity," sets itself apart from 'inter-' and 'multi-' disciplinarities by not originating from traditional academic disciplines (Nowotny et al. 2001). Transdisciplinarity, they say, instead emerges around context specific problem solving giving rise to new compositions of knowledge and knowhow that have practical utility. Mode 2 thereby raises questions about the place and role of disciplinary training in our understanding of contemporary knowledge work like engineering-business. Is the Mode 2 trend a reflection of dissolving boundaries between established domains like engineering and business, or is Mode 2 rather to be understood as a political imaginary, whose practical implications require further investigation and perhaps reconceptualization to understand?

Thomas F. Gieryn's seminal work on *boundary-work* has shown how the ongoing demarcation of boundaries between domains of knowledge often involves high stakes for its participants. Founded on the philosophical difficulty of making rigorous distinctions between science and non-science (Gieryn 1983), he defined boundary-work as the, "attribution of selected characteristics to [an] institution of science (i.e., to its practitioners, methods, stock of knowledge, values and work organization) for purposes of constructing a social boundary that distinguishes some intellectual activities as [outside that boundary]" (Gieryn 1983, p. 782). Although many prominent sociologists and philosophers of science such as Robert K. Merton and Karl Popper sought for a criterion by which science, in a stable, transhistorical and reliable way, could be distinguished from other forms of knowledge making, so far no one has succeeded.

[7] Jasanoff, "Designs on Nature," (2011).

Because Mode 2's success criteria are meant to apply to all knowledge productions, they can be seen to challenge the internal criteria of traditional disciplines' self-assessment. Mode 2's reframing of knowledge work is thereby likely to affect the demarcation dynamics performed from within multiple disciplines when they perform work under similar performance criteria to those that apply to other disciplinary demarcations. When applied to engineering and business, boundary-work provides us with an entry for looking at how disciplinary boundaries are being drawn, redrawn and negotiated in the context of Mode 2 knowledge production: What does it mean for the professional identities, the curricular content of educational programs, and for our understanding of the dynamics behind the institutionalization of engineering-business within higher education?

The Design & Innovation program's development, to which we now turn, presented a form of boundary-work that was driven by the teachers' need to re-justify their value to their host institution within a funding regime whose success criteria emphasized research's commercial application and social impact. In effect the Design & Innovation program provides us with the opportunity of having a gaze into how a branch of higher education attempted to demarcate its field of knowledge and methods to align itself with commercial innovation in order to measure up against performance criteria that would usually be associated with business. This observation leads to questions of how we can characterize the translation of broader imaginary developments into new engineering-business programs that internalize holistic features and user needs into their curriculum and how we can conceptualize their relationship to preexisting disciplinary demarcations like business and engineering?

20.7 DTU and the Reformation of Higher Education

In the late 1990s, DTU, the Danish epicenter for technical research, faced severe economic problems and found itself entangled in a revitalized political game regarding the institution's future. Declining numbers of students and budgets that heralded returning rounds of severe cutbacks – maybe even bankruptcy – threatened the once highly distinguished and politically sacred institution. The Konsistorium, the highest political body responsible for DTU's strategic decisions, was confronted with a difficult choice: Either to face severe cutbacks or accept a confidentially negotiated deal between the then DTU president, Hans Peter Jensen, and Minister for research, Birte Weiss. A deal that in effect would turn the public institution into an autonomous organization. DTU would undergo a reorganization that effectively replaced its collegial system with a top-down hierarchy with appointed leaders, a president, and an executive board with a majority of external members – predominantly appointed from the private sector. While the settlement resolved DTU's financial situation, it would also mean the end of academics' self-governance.

Following the instatement of the researchers' patent law in 2001 that enabled universities to patent publicly supported research, later the same year, the DTU-law was passed. In effect the DTU president received almost complete autonomy and unrestricted authority. The DTU law thus fundamentally transformed the legal basis upon which the Danish flagship for technical sciences could be ruled. But DTU was not alone to be reformed. Already in 2003, the reform "Time for transformation of Denmark's universities" which carried the subtitle "Strengthened leadership, increased freedom, stable economy" introduced the remaining Danish universities to the possibility of undergoing wide-ranging reorganizations similar to those implemented with the DTU-law.

Amongst the reform's initiatives, the most controversial and publicly disputed part was on universities' leadership. Not only was the democratic collegial system with its elected leaders replaced with a new system of commissioned leaders. The 'konsistorium' that had remained the highest-level decision-making body at Danish universities since the founding of Copenhagen University in 1479, was also replaced in the reform's efforts to 'professionalize' Danish universities. The minister of science, technology and development announced the reform as being the most substantial transformation of the Danish scientific system since the opening of Copenhagen University. The reform's official objectives were to 'open up' the university system "outwards to society" and improve universities' "decision-making competence".

The reforms marked a significant reconfiguration of Denmark's moral space for science. Inward looking self-assessment by intellectual peers that cherished integrity was replaced with professional administrations that strove for financial rewards that could secure the survival of the self-sustaining institutions. In effect the new economic space in which academic institutions and their employees operated had become significantly more dependent on how the surrounding society perceived its value and utility. Research groups now found themselves in a radically new institutional setup where the basis for legitimacy was no longer obtained by electing leaders that would be sympathetic to their intellectual projects. Instead formal responsibilities towards educational programs and the ability to attract students, external grants and industrial income became increasingly paramount to researchers' and teachers' survival. In the face of declining student numbers, DTU's new autonomous status emphasized its necessity to generate income in order to live up to its function as an economically self-sustaining organization. As we will describe in the following, there was a flipside to this tense economic situation in that it necessitated fundamental changes that would otherwise be difficult to sanction in the highly tradition-bound educational culture. New measures for attracting students gained renewed institutional legitimacy.

20.8 Higher Educators Strike Back: The Design & Innovation Program

Shortly after the DTU law was passed a group of researchers and teachers began the development of an entirely new engineering program that introduced new curricular as well as new pedagogical structure, and new inter-faculty collaboration. In 2002, roughly 1 year after the DTU law, the new engineering program "Design &

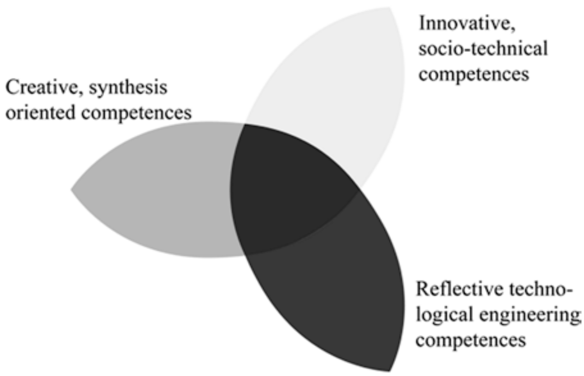

Fig. 17.1 The multidisciplinary composition of the design & innovation curriculum. (Jorgensen et al. 2011)

Innovation" was launched. The program was in no small part an objection against how engineering had been thought and taught at DTU.

> [T]he curriculum represents a radical innovation in engineering curriculum. Not least as it includes new disciplines covering socio-technical analysis and new approaches to design synthesis as well as integrates open ended project assignments in cooperation with companies and other actors in society. (Jorgensen et al. 2011, p. 1)

With outset in what the program's teachers saw as necessary competences needed for engineers to practice design in professional settings, the above Venn diagram (Fig. 17.1) illustrates the core structure of Design & Innovation's curricular composition. The composition was based on three equally important basic knowledge and skills components: 'reflective technological engineering competences' (dark grey), 'creative, synthesis oriented competence' (medium grey), and 'innovative socio-technical competences' (light grey). "[T]he multidisciplinary approach to engineering applied in the design & innovation program at DTU giving equal importance to the social and the technical sciences" (Jorgensen et al. 2011, p. 11).

Besides the noteworthy introduction of creative content including sketching and decision-supporting synthesis methods, the inclusion of social scientific content mostly from Science and Technology Studies (STS) was perhaps the program's most contentious supplement to the old distinguished and tradition-bound engineering institution. Making social science available to engineering students was not in itself controversial. However, making social science an accredited part of the core curriculum of an engineering program was a significant breakthrough for the institutionalization of the research group responsible for Design & Innovation program. In effect, social scientific teaching and research acquired formal representation within DTU's activities.

20.8.1 Pedagogics and Its Implicit Resource Politics

Rather than buying into the prevailing trend of large common courses that was delivered to hundreds of students from several engineering programs, Design & Innovation's mathematical and technical content was rethought from the ground up to fit its multi-disciplinary and collaborative vision. While generic courses enabled large lecture hall classes and thus ‘effective’ use of teachers’ teaching obligations, the idea behind the Design & Innovation program was instead to scale down and focus on creating an intimate relationship between teachers and students. By means of smaller numbers of students through restricted capsize on student admission and the use of ‘studios,’ known from design and architect schools, for lecturing and group work, the program was effectively sat up to ensure protection against generic engineering courses. While official reasons were coined in terms of curricular content and pedagogical approach, the choice of studios for teaching affected the distribution mechanisms for teaching resources. Instead of large lecture halls in which few teachers could cover course requirements of hundreds of students, resources would be more directly attached to the teachers who controlled the program. The composition of the Design & Innovation program thus represented a counter-move from the performing level against the centralization of power within Danish higher education.

Despite Design & Innovation’s deviation from the dominant scheme of standardized mathematical and technical courses and its implications for centralized resource politics, the condition of DTU’s student enrolment, meant that radical means gained more tolerance than usual. While the DTU law made the way for centralizing power within the newly implemented one-string administration, the same political context was paradoxically also responsible for emphasizing universities’ dependence on their researchers and teachers’ capacity to invent new innovative curricular and teaching approaches that would improve upon their income generating student admission numbers.

20.8.2 Reframing Identities and Professional Boundaries Within Engineering

> An important motivation from the university management’s side for providing the new education in design & innovation has been an interest in attracting more and new types of students having good grades from their high school graduation but not being attracted by the traditional engineering education curricula. The new educational profile has proven valuable for this purpose as it has recruited almost 50% of its students, from groups who explicitly would not have sought admittance to the engineering programs. The education has also been able to attract almost as many female as male students. (Jorgensen et al. 2011, p. 4)

The ability to open up ‘engineering’ and extend its appeal beyond what attracts the usual engineering profile and recruit students that would otherwise not have chosen an engineering program was paramount to DTU’s future. Although Design & Innovation’s aspirations to strengthen the position of reflexive social sciences at DTU were controversial, they were also a timely answer to DTU’s critical situation.

Besides its unique curricular composition, Design & Innovation also built on a radically different pedagogical approach to engineering education than that present at exiting DTU programs. Because of low admission rates, Danish engineering programs have traditionally not had access restriction. Whereas other DTU engineering programs classes on the first semesters front-loaded students with mathematics and physical sciences, Design & Innovation instead focused on projects and group collaboration through which students acquired both technical skills *and* competencies to apply them within the social context of group work. In effect fewer students dropped out – especially during the first semesters – Design & Innovation quickly attained higher completion rates than any other DTU program.

> The students seem to have embraced the new curriculum and the number of students' abandoning the education is very low. (Jorgensen et al. 2011, p. 8)

While most other engineering programs had plenty of empty seats to fill every year, Design & Innovation already from its first year had to reject more applicants than the program could accept. As a result, Design & Innovation demanded the highest high school grades average of any engineering program of its time in Denmark.

Contained within the innovative scheme of conducting new forms of collaborative project based teaching was a score to be settled with the predominant paradigm in Danish engineering education that focused almost solely on mathematical skills, engineering sciences and specialized technical knowledge. Traditional ideas of engineering fixated on technical, mathematical and analytical skills. The predominant imagination surrounding professional engineers was that they broke down problems into compartmentalized technical sub-problems in order to give them structure that could be subjected to mathematical representation and manipulation (Davis 1998). To the teachers behind Design & Innovation, this ideal was counterproductive because it promoted disciplinary silo thinking and compartmentalized sub-solutions rather than holistic thinking and 'complete solutions'. In contrast to analyzing, Design & Innovation built on the notion of Design Synthesis whereby practitioners of engineering design would draw together multiple disciplinary interpretations of shared design objects (Juhl and Lindegaard 2013).

As a consequence of its synthesis-oriented curriculum and project based teaching approach, Design & Innovation presented a completely new profile for design engineers that included collaborative competencies, creative problem solving, aesthetic skills, and a more developed sensitivity towards human and humanitarian aspects of engineering –sensibilities and competencies that in the eye of the general public had not before been associated with the professional identity of engineers.

20.8.3 Business Through Users

Whilst common interpretations of *innovation* in business terms center on economic goals and market growth, the Design & Innovation program represented an interpretation that was inspired by the notion of 'domestication' as portrayed in Social Construction of Technology (Bijker et al. 1987). Here, innovation is about users' adoption of technology and adaption within use-practices. In contrast to market analyses that assess sales potentials and design marketing strategies at the macro-level by constructing consumer categories and market segments, Design & Innovation instead investigated users' adaption of technology at the micro level in order to define goal specifications for engineering designs.

> The synthesis oriented competences of the DTU design & innovation program has therefore attempted to include user investigations and involvements as a basic mindset from the very first semester. Further the re-design activities of the second semester builds on studies of the use and problems related to existing products and technologies to provide the students with toolsets and approaches to tackle the demand side of products, services and systems. (Jorgensen et al. 2011, p. 5)

Whereas business domains' typical economic interpretations of innovation separate the 'demand side' from engineering domains' technology-oriented 'supply side', Design & Innovation presented an alternative and third interpretation whereby users' needs and adoption of technologies were integrated with understandings of technology development. By means of micro-sociological studies of user-practices, products' practical utility, affordances and social consequences, Design & Innovation integrated 'demand side' analyses with 'supply side' development through design specifications that was based on important lessons from user studies.

By combining social scientific methods to investigate use-practices, technical analytical knowledge and design synthesis competencies, Design & Innovation was setup to produce a new kind of holistic knowledge. Grounded in the epistemological principle of 'design synthesis' whereby representations carrying knowledge from different disciplinary approaches were drawn together, new design insights emerged (Juhl and Lindegaard 2013). Although business and economics literature was not included in the obligatory curriculum, the knowledge produced was intended to establish corresponding new use-practices and technological affordances –or what in marketing language could be called new 'business opportunities' or 'innovation'.

20.8.4 Inter-institutional Collaboration and Unsettled Politics

Another significant feature of the Design & Innovation program was that it had two faculties behind it. The program was based on a new form of collaboration between ten experienced teachers from two different faculties who invested heavily in developing its curricular content.

> The starting point for the development of a new engineering curriculum in design & innovation was based on the work of a group of ten devoted and experienced teachers of engineering design and social science subjects based in the departments of 'Mechanical Engineering' and 'Manufacturing Engineering and Management.' (Jorgensen et al. 2011, p. 8)

Although most educational programs belong to one single university department, which has the sole responsibility for defining the program's profile and for allocating teaching resources, Design & Innovation was from its outset a joint venture between two departments. Since no single faculty could cover the entire curriculum, the institutional re-engineering behind Design & Innovation at one and the same time demonstrated what was special and vulnerable about the program. The two-department faculty made coordination more demanding because it had to transcend intra-departmental concerns at the risk of getting caught up in inter-departmental politics.

At a time when university politics were being rewritten and science, technology and innovation policies were subject to constantly changing foci, one of the few things constant was that universities were driven towards profit making. The operation as autonomous economic agents within a competitive environment had turned control over resources into the most valuable political capital. At DTU, top-down decisions that redefined departments' areas of responsibility often clashed with bottom-up experiences from university employees, who felt that their professional identities and institutional legitimacy were jeopardized by the institution's positioning within the ever-more competitive intellectual landscape.

To the two faculties teaching Design & Innovation the political tumult was felt as the group responsible for teaching engineering design and mechanical engineering went through several departmental moves. First the group was moved from the department of Mechanical Engineering to Manufacturing Engineering and Management, and subsequently when that department changed name to Management Engineering, the group moved back again to Mechanical Engineering.

> When new programs are created and new institutions build the need for cooperation and the value of coherent curricula is obvious and resources often channeled to satisfy this task. When programs mature and the research career motives of the faculty supported by the measures of individual success in academic activities increasingly shadow for the tedious and often complex tasks of maintaining the coordination and continued improvement of the teaching program. Though many engineering universities claim to value curriculum and teaching improvements reality demonstrates that research activities are valued even higher. (Jorgensen et al. 2011, p. 11)

Once the Design & Innovation program became everyday-business, the conditions for its inter-faculty collaboration transitioned into a new state of operation. Where its initial start up was conducted under the status of 'special project', with extra resources allocated for developing the program, the following status was one of 'regular maintenance' where efficiency was the mantra. The extra resources that initially were allocated to build the new curriculum and attaining specialized teachers with the right mindset and other 'start up' undertakings were prioritized to other purposes. When new teachers were ascribed to teaching duties that had been painstakingly developed and negotiated to fit the program's unique demands with the teachers whom preceded them, no extra resources were available and some of the original pedagogical groundwork slowly eroded. As a result the coherent and holistic idea behind the program became increasingly difficult to fulfill as the Design & Innovation program transitioned into an every-day state of operation.

While many of the teachers involved in Design & Innovation saw the program's development as a necessary move to secure new positions and their research at

DTU, they soon realized that the resources that were promised slowly got redirected to other priorities. At a university where the ability to attract industry funding for new laboratory equipment meant that the university provided the housing for the new laboratories, the price was paid by those who had to be moved in order to free up the needed space. To Design & Innovation this was felt when real estate that used to be for classrooms and group workspaces was reallocated to new laboratories and private workshops. Slowly, but steadily, the conditions that used to support Design & Innovation's trademark pedagogic approach were recast to a degree where the teachers felt them like a straitjacket.

After 10 years of successful program building, 2012 became the turning point at which 26 researchers, including most of the social science teachers and originators of Design & Innovation, left DTU for another academic institution. In an interview on national television, several of the senior researchers expressed that the working conditions had become too hostile for them to continue their work at DTU. Despite that many of the implicated researchers were responsible for significant contributions to building and maintaining what had become the most successful educational program in DTU's history[8] – the teachers feared that the declining resources jeopardized their teaching and research, and ultimately threaten their future at the university.

While the 26 researchers' exit was an unprecedented event in Danish academia that entered national newspapers and primetime television, not a single word was mentioned about the fleeing researchers in DTU's own two newsmagazines. To testament that nothing significant had taken place, the acting DTU president, Anders Bjarklev, replied in an interview that: "We have about 4000 researchers and research-related employees, and many of them work with sustainability and innovation, thus the quality certainly won't suffer".[9] Scientific researchers and teachers were considered mere resources, and as such, they were easily and readily replaceable.

20.9 Discussion: Design & Innovation as an Engineering Business Nexus

Investigating the Design & Innovation program as an engineering-business nexus that was situated within the historical context of shifting scientific and higher education paradigms enables us to better understand the cultural constituencies surrounding its development. While Design & Innovation met resistance from a traditionalist conception of what true engineering entailed, shifts in the surrounding political environment created a unique set of conditions for novel and controversial thinking. Within the bigger picture, the curricular content that was introduced with the Design & Innovation program marked a clash between the rapidly emerging

[8] http://ufm.dk/uddannelse-og-institutioner/statistik-og-analyser/sogning-og-optag-pa-videregaende-uddannelser/grundtal-om-sogning-og-optag/kot-hovedtal/hovedtal2012.pdf

[9] http://www.information.dk/470336

political culture where credibility was exchanged with economic impact and traditional academic virtues that had to re-qualify their worth in economically defined terms of utility.

So what does a piece of Danish academic and higher education institutional history add to our understanding of the engineering-business nexus? In order to address this, we wish to reflect upon the Design & Innovation program's development in relation to three pertinent questions: (1) how the case enables us to think about nexus formations; (2) how we can characterize it as a nexus; and finally (3) provide a suggestion for what we can learn from the analysis of the nexus.

20.9.1 What Does It Mean to Be in a Nexus?

To begin with, what does a nexus mean? In order to provide some tentative definition and concreteness to the term 'nexus' we go back to the Latin work *nectere* from which the English language imported the word *nexus* during the seventeenth century. Nectere means 'to bind or tie' something together and thus illustrates some of the fundamental features of nexuses from which we will depart in our discussion of what we can learn about engineering-business nexuses from the Design & Innovation program.

To connect implies at least two different entities that are in some way being associated with one another. It also means that there is something gained from bringing this connection into being since the very act of tying them together would otherwise be pointless. Nexuses are in other words products of different things being actively brought together by which something new comes into being that would otherwise not occur.

The Design & Innovation program's development can be seen as nexus formations at several levels. A fundamental feature that transpired at all levels was the way in which externally infused necessity played a role in Design & Innovation's development. From the new social expectations of science and more holistic engineering (i.e., Mode 2) to universities' institutional autonomy and the increased pressure on individual researchers and teachers to secure income, fundamental changes were *necessitated*. With respect to the institutional context, the 'connection' between engineering and business was rather a product of changes in the social expectations that surrounded academic work and engineering, than something that developed from inside the engineering discipline. Analytically this implies that we should look more closely at the interplay between engineering, business and the surrounding society and how engineering and business are valued in order to understand the meaning of the engineering-business nexus. As exemplified by Gibbons et al.'s observations of science's transition from Mode 1 to Mode 2, expectations of social institutions can change over time and provoke significant transformations in existing institutions' purposes and processes. In our case, higher education and engineering addressed the new political expectations by forming new connections to non-technical domains that should provide renewed legitimacy by appropriating non-technical based values. As a result new nexuses were formed by means of new curricular compositions that articulated engineering's value on basis of its application to non-technical domains i.e., Design & Innovation.

Another important lesson relating to the creation of necessity is to look at nexuses as open for interpretation and negotiation among its involved stakeholders. When necessity called for DTU to act on its economic situation and especially its educational profile, nothing was pre-inscribed about what that might, or night not, entail. When the Design & Innovation program was presented as a solution, its success was allegedly an effect of the necessity created by the unique situation that sanctioned its implementation. While the merits of Design & Innovation's controversial curricular composition and pedagogical content in retrospective can be read as the logical solution, the program relied on being positively reviewed in its contemporary setting. At the time the political situation demanded that DTU to develop new connections between its hallmark, technical engineering, and other knowledge domains that could aid the revival of engineering's widely perceived status and attract more and better students. The open question was with what to connect? Design & Innovation presented an idea that, despite its controversial curricular composition, entailed a revised status for engineering that brought together: creativity, social awareness, and product innovation.

20.9.2 How Can We Characterize Design & Innovation in Terms of Nexus Dynamics?

The development of the Design & Innovation program entailed ideas that at the time resonated with overarching political tendencies – i.e. the application of science towards economic innovation. In this view, the program was not as much 'disruptive' in its redefinition of engineering as it provided continuity to widely held imaginaries against which engineering until then had remained politically insulated. Design & Innovation's development took place alongside a set of broader political events that were part of the changing political order in which the social value of knowledge work was increasingly determined by its marketability. Engineering as a profession and category of higher education was no longer in a position to resist its adaption to a new set of roles and identities which legitimacy was based on economic impact rather than internally defined esoteric technical excellence. The traditional popular portrayal of engineers as highly specialized narrow-minded technologist lacked the required capacity to attract students.

In this perspective, the Design & Innovation program can be seen as a curricular and pedagogical move to close the normative gap between widely held perceptions of engineering and where it ought to be in order to live up to the new social expectations of knowledge production. In no small part the successful implementation of Design & Innovation can be seen as a result of its unique capacity to bring together Mode 2's application emphasis with new 'holistic' visions for higher education.

When assessed in accordance with each respective imaginary, Design & Innovation did not present ideal solutions. Instead it challenged technical knowledge as engineering's signifying cornerstone, presented user-studies as proxies for market applicability and thus illustrates how nexus formations can bring together different levels of imaginaries into locally acting complimentary necessity constructs for which the otherwise unlikely becomes the uniquely qualified resolution.

In the edited volume *Dreamscapes of Modernity – Sociotechnical Imaginaries and the Fabrication of Power,* (Jasanoff 2015), Jasanoff argues that the nature of coexistence between imaginaries can be "in tension or in a productive dialectical relationship." (p. 4). Little is however done to quality the meaning of 'tension' and 'productive dialectical', and how the relationship between the two states of coexistence may look like. The Design & Innovation program came into being by acquiring a unique position within several imaginary formations. By providing a local solution to what was asked for by both Mode 2's application orientation, New Public Management's desire for autonomous institutions, and new holistic visions for higher education, Design & Innovation made itself a nexus which local meaning was at one and the same time consumed by, and consuming, multiple widely held visions at different levels. Design & Innovation thereby formed into something that by possessing the capacity to connect different coexisting visions of better futures harnessed the necessary political support to become institutionalized.

20.9.3 What Do We Benefit Analytically from Treating Something as an Engineering-Business Nexus?

The focus on nexus formations brings into questions not only what new the connected parts together bring, but also the very identities of the parts being brought together. Since the Design & Innovation program demonstrates how necessity brought engineering to seek up new definition through engagement with non-technical domains, the nexus formation entails what Thomas F. Gieryn calls 'boundary work' in which the very definition of engineering is demarcated from other domains. What is special and interesting about the nexus formation around the Design & Innovation program is that it expresses a meeting point between the normative registers of engineering and those of the sociopolitical context in which engineering education operates. The demarcation of engineering's professional identity entailed a negotiation between where the traditional technical discipline of engineering saw itself and where it would have to move in order to gain legitimacy within the new political order where economic self-sustainability and marketability ruled the day.

Design & Innovation's development and implementation at DTU reveals changes in the normative structures underlying Danish institutions of higher education. The new necessities brought to bear on the existing social institutions created a situation in which DTU had to reinvent itself and the value of its knowledge production in order to survive. As teachers and researchers behind the design of the new program felt the same necessity, we can see the nexus formation as a survival strategy that operated at several levels. While policy changes transpired universities' admirations, higher education including researchers and teachers, responses at each level reveal local interpretations of the new social expectations. In light of this we can see the curricular composition of new 'nexus oriented' higher education programs to function as proxies for assessing transformations within the normative fabric of their surrounding societies.

Although the program was declared to be a success almost instantly after launch, its developers soon realized that the expected payoff from their efforts was disproportionally distributed across the institution and wouldn't come to benefit their own situation. Although the neoliberal agenda pushed DTU to open up for bottom up initiatives that challenged the conventional conception of engineering, potential success and its related benefits remained firmly controlled by DTU. Whereas the intellectual product within the new education's curriculum was developed on a bottom up initiative the associated risks and rewards were institutional matters.

20.10 Conclusion

Although it is possible to discern engineering from business in the abstract, the two professional domains are entangled in their actual unfolding in society. In their everyday practices engineers develop and apply technology in order to produce solutions, artifacts and products that satisfy the needs of users and consumers. The development of technology is always mediated by the purposes, ends in view, and objectives of the engineers – and most often the directions of engineering activities are targeted toward the fabrication of products, artifacts and solutions that are held in value by users and consumers. Similarly, business – the domain that translates technology into market applications – is reliant on the fabrication of technological solutions, artifacts and products. The domains of engineering and business thus hang together in mutually constitutive and intricate ways.

In this chapter we have investigated how the hanging together of the two domains is enacted through political and institutional reform initiatives in higher education in recent time. In the post war period the relations between science/technology and market have been tightened in the US and in Denmark as in the rest of the western world. The sociotechnical imaginary of the time installed publicly funded scientific research as a basic driver for progress, wealth and prosperity in society. In the era of neoliberalism, ideas about private-public cooperation took central stage, and science and technology was seen as the source that could bring about processes of innovation. Throughout this historical development the links between science/technology and business/market have increasingly been strengthened and visions about the role of engineering has changed accordingly. Perceptions about the challenges facing engineering, and the strategies developed to overcome these challenges are now predominantly forged by imaginaries of technological innovation that can ensure competitiveness on national, organizational and individual levels.

The historical development thus strengthens the connection between the domains of science/technology and business/market. However, we also observe how this trend has nuances and is open to local interpretations, adaptations and modifications. Our study of the Design & Innovation Program at DTU draws attention to the contingencies and situated nature of how the domains are held together. Even though higher education is driven by sociotechnical imaginaries that install profitability and market mechanisms as the authoritative principles of innovation, we also witness counter movements that seek to redefine innovation in terms that resonate better with traditional values in academia. Visions of holistic engineering, reflectivity about sociotechnical issues, and processes of user-driven innovation have spurred a sociotechnical imaginary that install new moralities and meanings in the authoritative principles of innovation. 'The Hybrid Imagination' (Jamison et al. 2011) does not decouple the dominant sociotechnical imaginary of innovation, but coexist in tension with this vision. As innovation is envisioned differently here, the connection between engineering and business is also conceived differently. In this imaginary, business is no longer seen as confined to operate within the market, but more broadly as socio-technological engagement with citizens, consumers, users, etc. in society – or in other words Mode 2 inflected conceptions of domain specific 'applicability'.

References

Anderson, B. (1991). *Imagined communities: Reflections on the origin and spread of nationalism*. London: Verso (1983).

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (Eds.). (1987). *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge, MA: MIT press.

Bruun Jensen, C. (2011). Making lists, enlisting scientists: The bibliometric indicator, uncertainty and emergent agency. *Science Studies, 24*(2), 64–84.

Buch, A. (2012). Governing engineering. In S. H. Christensen, C. Mitcham, B. Li, & Y. An (Eds.), *Engineering, development and philosophy: American, Chinese, and European perspectives* (pp. 169–182). Dordrecht: Springer.

Buch, A. (2016). Ideas of holistic engineering meet engineering work practices. *Engineering Studies, 8*(2), 140–161.

Bush, V. (1945). Science, the endless frontier: A report to the President. US Govt. print. off.

Carney, S. (2006). University governance in Denmark: From democracy to accountability? *European Educational Research Journal, 5*(3–4), 221–233.

Davis, M. (1998). *Thinking like an engineer: Studies in the ethics of a profession*. New York: Oxford University Press.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy, 29*(2), 109–123.

Gaardmand, A. (1993). *Dansk byplanlaegning 1938–1992*. Copenhagen: Arkitektens forlag.

Gibbons, M., et al. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage.

Gieryn, T. F. (1983). Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists. *American Sociological Review, 48*(6), 781–795.
Jamison, A., Christensen, S. H., & Botin, L. (2011). *The hybrid imagination. Science and technology in cultural perspective*. San Francisco: Morgan & Claypool Publishers.
Jasanoff, S. (2004). *States of knowledge. The co-production of science and social order*. London: Routledge.
Jasanoff, S., & Kim, S. H. (2009). Containing the atom: Sociotechnical imaginaries and nuclear power in the United States and South Korea. *Minerva, 47*(2), 119.
Jasanoff, S. (2011). *Designs on nature: Science and democracy in Europe and the United States*. Princeton: Princeton University Press.
Jasanoff, S. (2015). Future imperfect: Science, technology, and the imaginations of modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of modernity. Sociotechnical imaginaries and the fabrication of power*. Chicago: Chicago University Press.
Jorgensen, U., et al. (2011). Foundations for a new type of design-engineers. DS 68-8: In *Proceedings of the 18th International Conference on Engineering Design (ICED 11), Impacting Society through Engineering Design*, Vol. 8: Design Education, Lyngby/Copenhagen, Denmark, 15–19 Aug 2011.
Juhl, J. (2016). Innovation science: Between models and machines. *Engineering Studies, 8*(2), 116–139.
Juhl, J., & Lindegaard, H. (2013). Representations and visual synthesis in engineering design. *Journal of Engineering Education, 102*(1), 20–50.
Lundvall, B.-Å. (1988). Innovation as an interactive process: From user-producer interaction to the national system of innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical change and economic theory* (pp. 349–369). London: Pinter.
Lundvall, B.-A. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning* (pp. 45–67). London: Pinter.
MacKenzie, D., & Wajcman, J. (Eds.). (1999). *The social shaping of technology*. Birkshire: Open University Press.
Nelson, R. R. (Ed.). (1993). *National innovation systems: A comparative study*. New York: Oxford University Press.
Nowotny, H., Scott, P., & Gibbons, M. (2001). *Rethinking science: Knowledge and the public in an age of uncertainty*. Cambridge: Polity.
Petersen, R. P., & Buch, A. (2016). Making room in engineering design practices. *Engineering Studies, 8*(2), 93–115.
Sábato, J., & Mackenzi, M. (1982). *La producción de technología. Autónoma o transnacional*. Mexico: Nueva Imagen.
Strathern, M. (2000). The tyranny of transparency. *British Educational Research Journal, 26*(3), 309–321. [Wiley, BERA]. http://www.jstor.org/stable/1501878.

Joakim Juhl BSc in Engineering Design and MA in Innovation Management, both from the Technical University of Denmark. He received a PhD in Science and Technology Studies from Aalborg University, Department of Planning and Development. He holds an assistant professorship in Design Methods and Synthesis in Engineering and Innovation at the Department of Planning and Development at Aalborg University. Joakim is affiliated with the Center for Design, Innovation and Sustainable Transition at Aalborg University and The Program for Science, Technology and Society at the Kennedy School at Harvard University. Currently Joakim contributes to the National Science Foundation funded project, "Travelling Imaginaries of Innovation: The Practice Turn and Its Transnational Implementation" that is hosted at Harvard Kennedy School by Pforztheimer Professor of Science and Technology Studies, Sheila Jasanoff. Joakim's recent work touches on the themes of Innovation Science, Innovation Policy and Science Governance.

Anders Buch Professor at Aalborg University Copenhagen Department for Learning and Philosophy. His empirical research area is focused on technological expert cultures, and his theoretical approach is primarily inspired by Science & Technology Studies, Practice Theory and Pragmatism. He has published articles and books on knowledge, learning, education, professionalism, and the professional development of engineers. Since 2016 he has served as chief editor of *Nordic Journal for Working Life Studies*. Presently he is preparing an edited volume with Theodore Schatzki for Routledge: "Question of Practice in Philosophy and the Social Sciences."

Chapter 21
Tensions Between Industry and Academia: Policy Making and Curriculum Development

R. Alan Cheville and John Heywood

Abstract Elsewhere we have discussed the tensions inherent to being an engineer, and argued they are both necessary and constructive. These tensions necessarily impact on the role of the teacher and the role of the students in learning, and therefore, the curriculum. Curriculum mediates between the needs and values of higher education and those of the larger social system including businesses in a capitalist society, which partially funds it and for which it is claimed to serve. The purpose of this chapter is to examine the implications of this view. It is shown with reference to current debates in the US engineering education community that understanding and embracing these tensions has radical implications for the design and understanding of the curriculum.

Keywords Systems thinking · Tension · Engineering education

21.1 Introduction

If the gist of this chapter were to be summarized in one sentence it might be that although society has increasingly adopted the conviction that money is an end in itself rather than a means to an end, this should not be true for engineering. While engineering seeks to make industrial production more efficient and thus has always been related to business, money is not the end towards which many engineers work. Rather engineers often view money, in a broad sense, as a means to enable other ends. Determining which ends engineers should strive for is a moral choice, for as William James pointed out (James 1912): "A moral question is a question not of what sensibly exists, but of what is good, or would be good if it did exist." This chapter concerns itself with questions about the worthwhile ends towards which

R. Alan Cheville (✉)
ECE Department, Bucknell University, Lewisburg, PA, USA
e-mail: alan.cheville@bucknell.edu

J. Heywood
Trinity College Dublin, Dublin, Ireland

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_21

different elements of society strive and how to balance these competing goals. More specifically, this chapter is concerned with how to best educate future engineers to represent the goals and values of their profession within a business—engineering nexus that skews increasingly towards business.

This chapter explores the intersection of the business—engineering nexus with educational systems by using engineering analogies to help to clarify broad ideas about the aims of engineering curricula (Bartha 2013). Educational systems are viewed within these analogies as infrastructures that are needed to support the engineering—business nexus and which adapt slowly to societal needs. Proposed changes to the ABET criteria that accredit engineering programs in the United States and some other countries are used as an example of such adaptation to illustrate these analogies. The intended audiences are engineers, engineering educators, and those on the business side of engineering who depend upon effective educational systems.

21.2 The Difference Between Tensions and Problems

Engineers self-identify as problem solvers (Pawley 2009) and are trained to find efficient solutions to problems which may cause them to see problems when what actually exists are tensions. Tensions are often conflated with problems but differ in several ways. A problem is a monopole, a unique entity that is framed as something to avoid. Tensions are by definition at least dipoles, and do not exist without two or more opposing and supported perspectives. Thus a tension is more dialectical in nature than a problem and lacks the purely negative connotations associated with a problem. This chapter asserts that tensions are necessary in defining and supporting change in an organization. There is a significant literature on tensions in the change and systems thinking literature as well as the business community (Schein 1992; Senge 2006; Stroh 2015).

The differences between problems and tensions are reflected in how these words are used. The word problem is typically used possessively—my problem or their problem—such that some entity causes or solves a problem. The use of tension is more descriptive and used to define a state. One typically speaks of solving problems where the solution serves to eliminate or mitigate the problem. Tensions, on the other hand, reflect a long-standing state of affairs characterized by a difference in perspectives or values without implying an imperative for change. This does not mean tensions are static, rather tensions often exist in dynamic equilibrium such that changing or eliminating a tension changes the state of the system. In this chapter the term system is used somewhat generically to apply to organizations across scales so a system is defined as "…an interconnected set of elements that is coherently organized in a way that achieves something" (Meadows 2008). Tensions thus arise from interconnections between elements within the system and require a change to the system itself if they are to be addressed. This definition of system highlights another difference between tensions and problems. Problems, particularly in engineering, tend to be subjected to a linear decomposition and solution process. Tensions represent the existing system in its entirety and therefore are more circular and nonlinear.

Although problems and tensions are often conflated, this error likely arises from human tendencies to see disagreements as a problem. Tensions do not necessarily lead to problems unless they are unnoticed, misunderstood, unaddressed, or when systems under tension do not have channels to foster meaningful dialog. When a tension is framed as a problem, it may seem unresolvable. Since the human response to situations that one does not have the resources or control to cope with is stress and long term psychological reactions to stress include a sense of dysfunction (Unsworth 2001), tensions are often viewed as intractable.

As every academic knows, tensions are manifest in educational institutions and thus influence how students are prepared to enter and succeed in the engineering—business nexus. Kezar (2001) points out that unlike businesses, universities have a unique culture and values; manifest a diffuse, loosely coupled, and often parallel decision making structures with shared governance; often have ambiguous goals; and are image and status rather than financially driven. In this environment dialectic change models explain many attributes of change that seem non-rational and non-linear. For example, a review of developments in Europe (Fumasoli et al. 2014) shows that trends towards autonomy in flagship universities are accompanied by a trend to accountability which has moved autonomy from an academic to an organizational dimension. This trend has resulted in a separate executive culture with its own norms, values and practices. The tensions between these two components "can be interpreted as tensions between two institutions".

There are similarly tensions within engineering which Priyan Dias (2013) has identified as ethical, ontological, and epistemological. The ethical tension is whether the influence of the engineering profession on society is, on the whole, positive or negative. Ontologically it is not clear whether engineers are classified primarily as scientists or managers. The epistemological tension arises around whether theoretical or practical knowledge forms the basis of engineering work. Dias frames these ethical, ontological, and epistemological tensions more globally as a tension between identities of *homo sapiens* (rational man) and *homo faber* (making man); i.e. between understanding and transforming. Debates between teaching engineering as a science or engineering as a practice are well documented historically (Seely 1999).

Tensions in engineering education were identified in a recent workshop that drew participants from a small but diverse group of faculty who came together to explore the intersections and differences of their interests. In the workshop the tensions shown in Table 21.1 emerged organically through participants' dialog (Cheville and Heywood 2016). Framing common issues as tensions rather than problems was seen as critical to making progress on seemingly intractable issues in engineering education. It is worth noting that these tensions focus on curriculum rather than academic management, likely because there were no professional administrators present.

Another recent example of tensions in engineering education are proposed changes to the ABET criteria used to accredit engineering degree programs. When ABET modified student learning outcomes to focus more on instrumental skills,

Table 21.1 Tensions identified at post-ASEE interdivisional workshop

Topic	Dialectic poles		Fundamental tension
Knowledge and epistemology	Theoretical	Practical	Knowledge gained from practice is not valued. But with age professionals increasingly base their work on experience.
Assessment	Process	Product	Should one assess the process of education or the product (student outcomes, e.g. ABET)?
	Objective	Authentic	Objective assessment places the ability to measure an outcome above the usefulness of that outcome in authentic practice.
Aims of education	Industry needs	Educating individuals	There is a long standing tension between educating students for jobs or as an individual.
Students and student experiences	Actual impact	Societal impact	What we provide students as projects often does not match the lofty language we use to discuss the ideal of an engineer.
	Depth	Breadth	How does one create the proverbial T-shaped engineer under the significant constraints most programs face?
Identity	Engineer first	Intersectionality	Some populations are unwilling to take on a single identity, yet a tension exists between the professional "do whatever it takes" image of an engineer and the need to shed this identity.
Teaching	Content	Experiences	Balancing the disciplinary content needed to do engineering work with the opportunity to learn from applying that content in practice.
Diversity and inclusivity	Inclusion	Professionalism	The need to be more inclusive can be in tension with the desire of programs to recruit and admit the "most talented" students.
Practice of engineering	Object-centered	Human-centered	How to maintain an ethical stance when engineering practice is often focused on objects and materials that are manipulated for human ends.

many in the engineering education community saw a negative impact on the professional identity of engineers. However many of the engineering societies of which ABET is composed welcomed the changes since they were perceived to better support objective assessment and were more internationally compatible. In this case tensions arose around identity, diversity, assessment, and the aims of education.

Tensions are by no means confined to academia, and numerous examples exist in both business and government. For example Dodd and Favaro describe three tensions faced by every company: profitability vs. growth, short vs. long term decision making, and focusing on the whole vs. parts (Dodd and Favaro 2006). Similarly there are organizational tensions in knowledge transfer between dense and sparse social networks and stable and changing group membership (Argote and Ophir

2002; Schein 1992). Examples of tensions in government are much in the press at the writing of this chapter such as Brexit or the US presidential election. Tensions also exist between government and business, many of which are played out in regulatory spaces. Well documented examples are proposed regulatory changes to the finance sector following the 2007–2008 recession (Foroohar 2016; Turner 2015).

21.3 The Relation of Tensions to Beliefs, Attitudes, and Values

The positions held by both individuals and organizations that place them in tension with others are based both on conflicts between interests and differing beliefs, attitudes, and values (Rokeach 1968); henceforth referred to as a credo (Aubert 1963). While often used interchangeably, beliefs, attitudes, and values are generally understood to have a hierarchical order. Generally beliefs are internal, need not be supported by rational argument, and may not be apparent or even conscious to their holder. Values stem from beliefs and reflect the worth we attach to ideas, actions, objects, or others. Attitudes are how beliefs and values are expressed through action, but espoused and enacted values need not align. Since differences in credos can lead to tensions, organizations seek alignment between individual and organizational credos through hiring, education, environment, rewards, etc. (Argote and Ophir 2002; Schein 1992). When such efforts are successful they allow individuals to adjust credos to their environment which is a purpose of education and necessary to self-management and advancement in an organization (Drucker 1999).

Of course not all efforts to change credos are benign in intent—e.g. the current geopolitical crisis with ISIS—nor are the tensions that arise from differing credos necessarily problematic. While the tensions that arise from different credos can create problems, talking to others who see the world differently is critical to self and organizational development. Immutable belief systems do not allow an individual to cope with change and lead to organizational stasis. Similarly lack of, or inability to articulate, a credo makes it difficult to act in times of uncertainty and inhibits development of identity. There is some optimal range between the extremes of vapidness and dogmatism which requires wisdom and experience to navigate.

In summary, an individual's traits, upbringing, and experience develop beliefs, attitudes, and values, i.e. a credo, that in turn influences their relationships. The same is true of organizations. Given that both individuals and organizations are defined in part by internal and external tensions, the capacity to function is determined not only by their capabilities, but by their credos, their awareness of them, and their ability to navigate effectively in scenarios in which these credos are in tension with those of others. This requires practical knowledge, or wisdom (Aristotle, Nichomachean Ethics, 1140A1-23) and tensions ideally result in learning which is necessary for both individual and organizational advancement.

21.4 Tensions, Organizations, and Learning Systems

Tensions are necessary for the maintenance of organizations as learning systems. By preparing students to navigate tensions in the workplace universities increasingly serve as a necessary infrastructure that supports the engineering—business nexus. Changes in work habits, technology, mobility, and globalization have increasingly fragmented societies to the extent that we are living in a plurality of social systems (Burns 1966) which can lead to increasing conflicts between disparate beliefs and values. Such fragmentation puts an increasing premium on being able to navigate tensions in one's life and work. Current trends in the workplace (Jones 2002) include teams that cross organizational boundaries, less hierarchical organizations, less management, employees who need to be self-directed and manage multiple aspects of their own work life, and high levels of interconnection both to other employees and customers. This broad trend has been labeled as "upskilling" reflecting the raised expectations for employees, who require traits previously expected from management. Thus graduates from engineering programs must know how to work in flatter organizations, identify opportunities, and be self-actualizing. Holton (1998) points out that the current model of higher education does not necessarily prepare students for this environment.

Students thus need "navigation skills" which are developed when existing preconceptions are challenged in environments that are psychologically safe (Schein 1992). Because tensions are often framed as problems, and engineering is focused on problem solving (Pawley 2009), this learning outcome may not be adequately addressed by engineering education as it is currently constituted. This lack is particularly felt when engineers (specialists) are put in management positions and need to synthesize information framed in diverse role-specific perspectives but their carefully developed schemata cannot make sense of the data they are receiving (Hesseling 1966). In this case they need to have experience looking at problems from a variety of perspectives and give credence to specialties beyond their own.

Within an organization espoused goals ideally let individuals with different roles share a common purpose and create an internal culture that gives members a sense of belonging (Schein 1992). However such cultures are not uniform so within an organization individuals approach issues from different directions based on their role, credos, and past experience (Pfeffer and Sutton 2000). This has been described in engineering firms by Bucciarelli (1996) and is why negotiation is central to engineering work (Kallenberg 2013; Trevelyan 2014). Roles shape people, but people also bring their credos into roles so individual credos become integrated into the fabric of an organization (Elsbach 2002). Furthermore individuals, particularly those in more senior roles, are generally given considerable leeway in interpreting their work so individual credos influence organizations, albeit sometimes over long time frames (Meyerson 2001).

For example within higher education generally, and engineering education more specifically, a program's curriculum reflects faculty beliefs about the aims of education and what the foundational knowledge needed to be an engineer should be. Although faculty within the same department need not hold similar beliefs about the aims of education (Schiro 2012) they negotiate, often with great difficulty, a curriculum. These negotiations are typically driven by individual credos and experiences, minimally informed by research on how people learn, and by faculty interest in particular segments of disciplinary knowledge. The organizational pressure to create curriculum does not, however, mean that the faculty arrive at a common belief system. Rather the shared value of academic freedom defuses tension by giving individual faculty necessary control over individual course decisions.

From the students' perspective credos, tensions, and the rationale for different faculty pedagogy are likely invisible. Thus the learner needs to navigate hidden, but never-the-less real structures, in his or her education. Given that learners have their own credos it follows that such navigation does not proceed solely by the formal map of the curriculum but also through personal relationships, mentoring, and courses that hold particular appeal to students (Chambliss and Takacs 2014). In this sense the diverse faculty credos that are negotiated to form a degree program benefit students by developing a variety of perspectives and finding mentors who align with their needs. When student credos are in conflict with instructors', cognitive dissonance results. This can either positively or negatively impact learning depending in part on the strength of student-teacher relationships (Heywood 2000 p. 182).

The proposed changes to ABET accreditation criteria in the United States serve as an example of how such tensions indirectly impact students. The changes were generated by a defined process ABET saw as beneficial to its organizational goals aided by considerable feedback from its stakeholders, primarily engineering professional societies. At the end of a multi-year process some learning outcomes were combined and others—that aligned with credos of faculty who identify themselves as engineering educators—were eliminated. This group, experts on the actual processes and limitations of program assessment, raised strong objections since they had put in considerable prior effort to align programs with ABET outcomes. The engineering education community engaged in a grass-roots effort to resist the changes. Based on written exchanges (Flaherty 2015; Rogers 2015; Slaton and Riley 2015) and face-to-face confrontations, the intensity of the clash over credos seemed to take both sides of the conflict by surprise. The engineering education community was surprised that this effort had been going on without their knowledge or input, and ABET was surprised at sudden opposition to a process they thought they had managed well. ABET created a social world consisting of evaluators and stakeholders in which they operated procedurally towards a defined goal. ABET did not, however, effectively manage the transformation from the credos underlying EC-2000 favored by engineering educators to a more evaluator-centric set (Elsbach 2002). Since the process of change did not include some credos, stakeholders whose credos were violated created tensions to force a readjustment. This example shows that external tensions were needed to stimulate ongoing reconsideration of the changes which can have a significant effect on how future engineers are trained and thus what engineering is.

Understanding how credos shape behavior and how to adjust one's role at need applies to any role in any organization. No matter their position within the organization a worker needs to interpret their role to some degree as well as interpret and respond to the positions of others. The need for some level of autonomy has always been present, but changes in how businesses are organized makes the need for learning and adaptation more important in the twenty-first century.

21.5 Theory X_T vs. Theory Y_T

How can engineering programs better teach students to navigate organizational tensions? In the 1960s McGregor developed theories of human motivation and management, Theory X and Theory Y, that contain contrasting assumptions of worker motivation (McGregor 1960). Theory X assumes that workers are extrinsically motivated and thus need highly regulated and structured work environments. Theory Y, on the other hand, assumes the workers are intrinsically motivated and encourages worker autonomy in a participatory and flexible work structure. This section uses this contrasting theory framework to describe how individuals or organizations respond when faced with an issue or problem. In the first model, Theory X_T (where the subscript T stands for tension), leaders identify goals and problems, develop a solution path, then they address issues procedurally using organizational resources. The second model, Theory Y_T, assumes the issue arises in part from existing, but perhaps invisible organizational tensions which are becoming prominent due to some internal or external influence.

Both of these theories are represented in graphically in Fig. 21.1. Theory X_T frames issues as problems that are a-priori assumed to have a solution, i.e. change of sufficient magnitude that the problem is resolved. Theory X_T posits that a solution can: (1) be causally achieved by some action or coordinated set of actions by a set of individuals responsible for the solution, and (2) some path to a solution can be mapped out in advance so that actions can be planned even if they need to be modified at a later time. In Theory X_T the change agent is an engineer or manager who plans the future desired state and works rationally towards it. Theory X_T is represented by tools such as logic models (W. K. Kellogg Foundation 2004) and theories of change (Connolly and Seymour 2012).

Theory X_T is commonly applied in engineering programs. The curriculum is an example in which a sequential series of carefully planned courses is designed to develop student knowledge and skills. A map of courses similar to the top part of Fig. 21.1 helps faculty and (to a much lesser extent) students understand the pathway determined to be most effective for professional development as an engineer. On a larger scale ABET has implicitly adopted a Theory X_T model in which engineering stakeholders define program requirements which are framed as student learning outcomes. This model is then loosely imposed on faculty who develop a continual quality improvement process for program improvement. ABET similarly used Theory X_T thinking in the process of changing their criteria where the

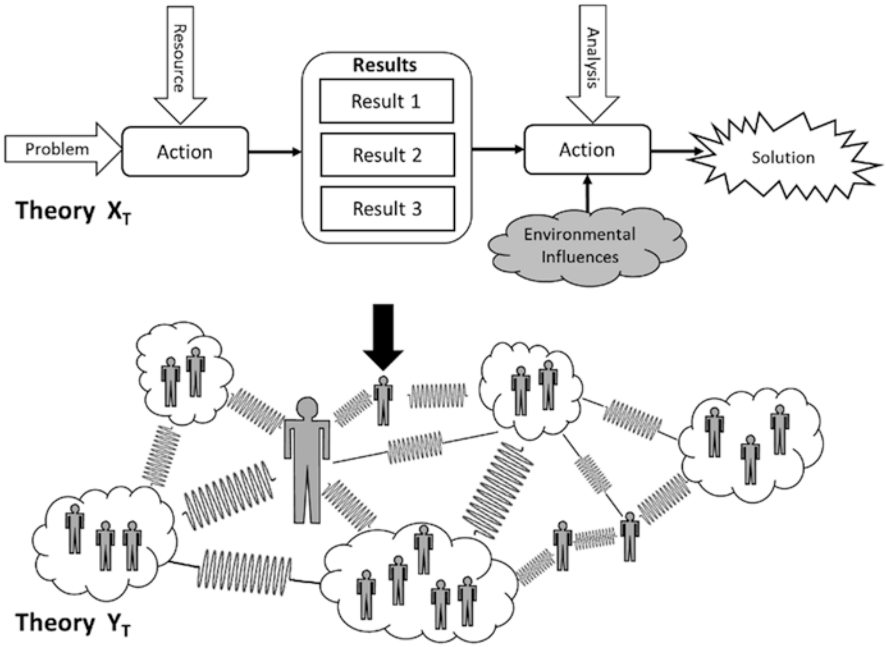

Fig. 21.1 Graphical representations of Theory X_T and Theory $Y_{T.}$ The forms are representative only

challenges for program evaluators led to a protracted effort to analyze the problem, seek feedback, then take action.

In contrast Theory Y_T views issues as tensions between agents or groups within an ecosystem that are in dynamic equilibrium. The tensions are not designed into the system, rather they arise from rational or historically defensible positions taken by actors or organizational units. The fact that connections can involve three or more groups allows neutral parties to help mediate dissensus (Aubert 1963). Change in Theory Y_T occurs through making these relationships transparent, thus enabling actors to see their position in new ways and allowing them to reframe the narrative underlying the overall system. A critical step (Stroh 2015) is getting individuals to recognize their role in supporting the tensions that define the overall system. Problems are not solved in the linear sense of Theory X_T since any rearrangement lessens some tensions while strengthening or creating others. Thus the role of a change agent is not resolution but adaptation. It is for this reason connections between individuals and groups are drawn as springs. A force on one part of the network (black arrow) can shift relationships in the entire network but the overall system retains a common configuration. Theory Y_T has analogies with complex system models used for social change (Meadows 2008; Stroh 2015).

Organizations that adopt a Theory X_T model are effective if they work towards similar ends with shared values. Under Theory Y_T interdependency and diversity within the organizational ecosystem are more important as are continuous evolution and free flow of information since they make organizations more resilient. In Theory X_T plans are made and followed and elements of the organization are seen as resources to that mission while under Theory Y_T the organization evolves as one group identifies and acts on opportunities, which eventually reshapes the power balance and thus the organization. If ABET, for example, had adopted a Theory Y_T perspective they would have sought to understand how the credos of program evaluators or faculty in programs under evaluation created the observed difficulties and lack of innovation and then devised some form of retraining. In the case that the tensions were systemic, i.e. built in to how ABET is constituted, then a more significant effort of reorganization would be called for.

Like Theory X and Theory Y, organizations do not choose to adopt either Theory X_T or Theory Y_T in a binary fashion nor is either theory objectively right or wrong since each has domains of applicability. However focusing too much on one at the expense of the other can have negative consequences. As will be discussed below Theory X_T thinking driven by financial goals has impacted the intersections of business and engineering. While specifics vary, overall when organizations narrowly focus on a limited set of metrics, weaken connections between groups, and let one point of view dominate then performance and morale eventually decline, even if this approach is successful in the short term.

In summary Theory X_T and Theory Y_T frame two different ways organizations deal with tensions with both engineering programs and accreditation bodies predominately adopting a Theory X_T approach. As discussed in the next section, this approach lets programs manage a large body of specialized content knowledge but may leave students unprepared for their transition to the workforce in an era when the skills called for in Theory Y_T are increasing.

21.6 Complex Individuals, Complex Curricula

In higher education the predominant Theory X_T approach defines learning outcomes for students then develops a curriculum and courses to help students meet these outcomes. However underneath this visible layer lies a set of values, myths, and deeply held faculty beliefs that are often in tension with each other. It is this invisible structure of Theory Y_T which has led to a particular instantiation of a curriculum rather than some other curriculum. These beliefs are not taught to students explicitly, but still inform the beliefs they develop about engineering, its relation to society, personal epistemologies, and the value of future career pathways. In higher education this is typically called the “hidden curriculum” (Margolis 2001). The mindset engineering degree programs adopt—the relative weighting of Theory X_T and Theory Y_T—thus impacts on how future engineers are prepared to enter practice. This section explores the intersection of these theories in engineering education, highlighting that both Theory X_T and Theory Y_T approaches are needed to prepare students to thrive in a world where there is increasingly less separation between skills traditionally defined as management or engineering.

The conceptual models of learning and competence that higher education stakeholders—students, faculty, parents, industry, government, etc.—hold determine the structure and process of education. We are currently in a time in which complex financial pressures (Hale and Viña 2016), an under-performing economy, and the predominance of business narratives have resulted in a more utilitarian, or Theory X_T, view of education that focuses on defined outcomes, rigorous assessment, education as preparation for work, and the lifetime return on investment for a degree. If engineering education is to prepare students to navigate constantly changing career pathways it will be necessary to expand the ways we prepare students beyond these Theory X_T models. From the 1970s onward it has been shown that a purely *tabula rasa* (blank slate) view of students based on Theory X_T is not as effective as integrating some active learning (Johnson and Johnson 1993). The reason for this is that education has a strong social element and both knowledge and skills are developed in relation to other persons. It may, however, be difficult to develop a Theory Y_T curriculum if one's models of learning are based on Theory X_T approach. Although educators with a Theory X_T model recognize that credos impact the effectiveness of learning, the fact that students come from a variety of backgrounds typically remains a second order effect compared to teaching content. Some pedagogies such Project-Based Learning (PBL) challenge this view, placing content subservient to project needs (Woods 1996). However PBL still focuses on person-artifact rather than person-person interaction unlike Theory Y_T which places connections/tensions between credos at the forefront.

Both theories are necessary in engineering education. Without the specific knowledge and skills of an engineer students will not be able to create value for their employer, but without being trained to understand the basis of other's perspectives they cannot navigate tensions in an organization and thus are limited as professionals. As related to one of the authors by a hiring manager in a large aerospace engineering firm (private communication) students who lack either set of skills are not hired while those that have both are. The more interesting case borne out by experience in this firm was that employees who lacked the skills represented by Theory Y_T but had those imparted by X_T curricula could be productively utilized but were not happy and soon left the organization. Those with Y_T but who lacked X_T moved quickly into technical management but were ineffective because they were not respected by those they managed who valued technical competence.

The above anecdote suggests an engineering related analogy. If one imagines plotting student preparation on a Cartesian axis with the amount of X_T on one axis and Y_T on the other it will look like the Argand diagram that is used to represent complex numbers. Complex numbers, composed of real and imaginary parts, have been used since the sixteenth century to solve algebraic problems that would be intractable otherwise and are common in engineering. This representation allows one to consider a student's education as having both X_T and Y_T components. One might frame this as X_T+jY_T with the real part arising from defined knowledge and skills developed through Theory X_T forms of education and the imaginary part representing the individual's ability to navigate tensions of Theory Y_T. The term "imaginary" does not mean "nonexistent"; rather is a historical misnomer of a necessary mathematical representation. For example while engineers do not routinely measure "imaginary quantities" in their work, complex numbers are required to determine solutions to many engineering problems. By analogy the Y_T portion of education is no less "real", rather is not as straightforward to teach or assess. While clearly a person is not reducible to a number—real, imaginary, complex, rational, or irrational—this analogy captures the need to include both forms of education.

In educating the complex individual the X_T part is addressed through standard modes of curriculum and attempts to make learning visible through processes such as grades, assessment, accreditation, and other "outputs" of traditional educational systems. It is this aspect, for example, that ABET addresses through their criteria that cover learning outcomes, curriculum, student, faculty, and facilities. The Y_T component, however, is built not only from coursework but also through personal connections such as friendship and mentoring. The Y_T component was well articulated by Newman in *The Idea of a University* when he spoke of education as a "formation of mind" (Newman 1852):

> But a University training is the great ordinary means to a great but ordinary end; it aims at… supplying true principles to popular enthusiasm and fixed aims to popular aspiration, at giving enlargement and sobriety to the ideas of the age, at facilitating the exercise of political power, and refining the intercourse of private life. It is the education which gives a man a clear conscious view of his own opinions and judgments, a truth in developing them, an eloquence in expressing them, and a force in urging them. It shows him how to accommodate himself to others, how to throw himself into their state of mind, how to bring before them his own, how to influence them, how to come to an understanding with them, how to bear with them. (p. 207)

Newman's writings emphasize that these benefits of education arise from confronting beliefs and values foreign to one's own upbringing in community with others.

While there has been considerable progress on valid, objective measures of the X_T part of learning (Heywood 2000), the part related to Y_T remains harder to assess since it is built from an individual's life-long reflection on their experiences and struggles as mediated through their family, friends, community, and faith. Given that it is not moral to compel a person to reveal their beliefs and values, faculty may not even be aware of this component without developing personal or mentoring relationships (Chambliss and Takacs 2014; Mentkowski 1999). It is tempting to say that because the imaginary component is not easily measurable it makes little difference to education, but it has a strong effect on interactions with others.

Integrating the Y_T component of curriculum with the X_T part remains a future challenge for engineering education. Currently the large volume of content knowledge in most engineering curricula limit students' exposure to alternative viewpoints and allows little exploration of personal credos. One possible approach is to make more explicit the unique values of engineering as distinct from business, science, or other disciplines. While most primary and secondary schools emphasize the values of science, college is most students' first exposure to engineering. Additionally work needs to be done to both define and discover the best way to teach engineering values. The issue of what it means to be an engineer and to develop one's own engineering values will likely require students to engage with a deeper philosophy of engineering that crosses over into ontology and metaphysics than most engineering ethics courses currently address (Davis 1998; Goldman 2004; Kallenberg 2013; Koen 2010). Curricula further need to illustrate how tensions are necessary for the survival of an organization and prepare students to effectively navigate these tensions in their professional lives; currently this is attempted through teamwork but not in a way that makes explicit how to make controversy constructive (Heywood 2000; Johnson et al. 2000). Engineering education could explore using active learning techniques from disciplines like the social sciences where tensions are made explicit (McKinney and Heyl 2009).

While these practical suggestions may have impact, ultimately the complex individual is not developed through courses but rather through personal relations (Chambliss and Takacs 2014). In this case more systemic changes to engineering education are needed to give students opportunities to explore the values of engineering and synthesize them with their own credos. In a Theory Y_T approach these personal connections would drive learning. Philosophical approaches which focus on personal interaction (Buber 2010; MacMurray 1961) may provide a starting point. Another useful perspective is Bruner's conception of narrative understanding (Bruner 1987) that occurs parallel to more rational forms of cognition as do Amartya Sen's ideas on capabilities and functioning (Sen et al. 1987). The credos important to Theory Y_T have elements of personal narrative and can be changed by techniques known as story editing (Wilson 2011) or giving more narrative agency to students (Cheville 2016).

While the discussion above focuses on engineering education, the same argument applies across other disciplines that focus on preparing students to work in a professional environment where they must deal with complex, human-derived problems. These include management, teaching, and politics/policy. The basic argument is that complex decision making relies on creating mental models, or schemas, of complex, interconnected systems. While such models are always incomplete and biased, overly simplistic models derived from a single credo are more likely to lead to bad decisions in a world increasingly defined by interconnection within networks. For example trends in management schools discussed by the Harvard Business School include the impact of technology, business ecosystems, and globalization (Silverthorne 2011); these all rely on interconnected networks.

The recent ABET controversy illustrates the complex student analogy. ABET dropped, changed, or integrated program outcomes that program evaluators found difficult to rate. Among these were those addressing broad education, knowing professional and ethical responsibility, and lifelong learning, i.e. those that aligned most closely with the Y_T component of the engineering curriculum. The revised criteria were supported by many engineering professional societies such as IEEE and ASME while the most vehement criticism came from those engineering educators most familiar with how the existing criteria have developed the Y_T aspects of engineering curricula.

This example is a microcosm of larger tensions within society between engineering and business. Engineering's focus on efficiently solving problems has enabled it to serve as a useful means to ends defined primarily by business. From a Theory X_T

point of view revising accreditation outcomes and curricula to focus learning on industry needs is a rational step. However from the Theory Y_T perspective the changes will reduce those parts of students' education that help them promote and defend personal and professional credos. As the next section discusses, this can have negative long-term impact on individuals, organizations, and society.

21.7 The Role of Education in Maintaining Tensions

Engineering and business have always worked hand-in-hand and it is generally accepted that this is a beneficial relationship. Early studies of engineering education (Mann 1918) highlight how the education of engineers was designed to meet the needs of industry as well as create a profession of production that would have the status of law and medicine (Percy 1945). The aspirational goals for engineering education framed by these studies sound much like those of today's business programs with a strong dose of craftsmanship included (Cheville 2014). Others (Froyd et al. 2012) have documented that as engineering education has evolved over time the focus has shifted towards integrating science into engineering (Grinter Report 1994) and being informed by rigorous research (Froyd and Lohmann 2013). Throughout these changes engineering and business continued their partnership. The synergy between engineering and business is supported by a narrative in which finance develops new ways to create mobility in capital which through a free market then finds and funds competitive businesses which hire the most able engineers to create the most worthwhile technologies which, in turn, leads to economic growth and societal advancement.

This narrative—along with rapid growth in engineering knowledge and technique, outcomes based accreditation, and the 4 year professional curriculum—has resulted in engineering programs being increasingly organized on Theory X_T models. Here both technical expertise and professional skills such as goal setting and teamwork are valued. While these skills are vital for engineering graduates (Carnevale et al. 2011) because they allow students to transition more easily to the workplace they emphasize a Theory X_T view of an engineer's role. Since higher education is many students' first exposure to engineering their view of the role of an engineer is shaped by college experiences and their credos may tend towards Theory X_T, producing graduates whose identity as an engineer centers on these abilities (Cech 2013). While college is not the only influence on engineers' credos, which are also strongly shaped by their workplace environment (Vinck 2003), never-the-less the cumulative effect of Theory X_T students entering organizations that value these skills may be self-reinforcing, sustaining the believability of this narrative.

Is this narrative accurate, and what is its overall impact on society? Following the 2007–2008 financial crisis this predominant narrative is increasingly being questioned. Adair Turner (2015) has summarized the role finance played in the 2007–2008 crash and subsequent recession, arguing that while finance offers more mobility for capital this does not in itself create societal value. Turner claims that while capital is necessary to fund engineering projects that benefit humanity, over time the fraction being invested in goods that create real value has dropped. Currently 85% of investments go into real estate and other financial instruments that heighten inequality and extract a "finance tax" on societies. Other examples of the systemic impact of the dominant financial narrative are discussed in Foroohar (2016) who documents how the theories taught in MBA programs have resulted in credos that drive organizations to act in ways that are immoral. This is an example of the double hermeneutic in which theory impacts on the world, thus generating evidence for the phenomena explained by the theory (Giddens 1987). Reich (2016) documents pervasive political and societal impacts including the negative long term economic impact on nation-states caused by policies that predominately benefit shareholders including rising inequality, asset-stripping from businesses, loss of jobs, and the decline of public infrastructure.

As business and finance have come to play a larger role in national economies and increasingly drive politics and policy in the United States (Friedman 1970; Powell 1971) these value systems have dominated those of other fields, including engineering (Reich 2016). Through a series of case studies Foroohar (2016) documents how in the century since engineering education was established in the US to bring scientific practices to industry the values of engineering and business have increasingly diverged as all parts of society, but particularly business, have been affected by financialization. These changes have been particularly profound in the last four decades and have led to issues such as the recent VW emissions scandal and Flint water crisis as well as the infamous Ford Pinto gas tank (Kallenberg 2013), the failing report card on public infrastructure in the US (American Society of Civil Engineers 2013), and the GM ignition switch (Foroohar 2016) in which engineers have acted counter to their own ethical canon of human welfare in the interests of finance. These values are now working their way into higher education which is adopting finance driven governance models and promoting the value of education in increasingly utilitarian terms. For example, financial metrics such as lifetime return on investment are now used in evaluating universities.

The challenge faced by society at this point in time is to ensure investment creates broad societal wellbeing rather than reinforce inequalities. Turner, Foroohar, and Reich each propose solutions involving reform of finance, regulation, education, policy, and investing in infrastructure and industrial production. What these authors do not address is the need to also address imbalances in the engineering—business nexus. Engineering educators have a role in restoring balance by discovering how to integrate models of education that are not solely based on Theory X_T. While there have been significant efforts and intentions to develop a more complex engineer (Clough 2004), the actual trajectory of engineering education remains focused primarily on developing the real, X_T, rather than the imaginary, Y_T, part of the student. Because the changes needed are not merely pedagogical or curricular but arise from tensions and are systemic in nature, faculty with X_T perspectives may lack needed models of change.

A Theory X_T approach can change outcomes but does not change a system; rather such change requires a much more circular, complex, and humble approach (Meadows 2002). Systemic change requires each agent in the system to understand how his or her own practices contribute to the issue being addressed (Stroh 2015), an approach better supported by Theory Y_T. With this view of the engineering—business nexus, the role of engineering education is not only to serve and support business by providing technically competent employees but also to prepare graduates to navigate organizational tensions while representing and supporting engineering credos. The modern university fills many roles in society. While teaching and research are important, a historic function of the university is to be a repository of knowledge and values. From this perspective disciplines serve as anchors for tensions, ground students in the credos of the discipline, and teach students to navigate tensions as a representative of the discipline. For engineering this is students committed to the moral good of human welfare (Cheville and Heywood 2015).

While highlighting tensions may seem counterproductive, there is increasing evidence that effective organizations balance both Theory X_T and Y_T approaches. Here success come from working towards a commonly agreed upon goal while supporting dialog between different perspectives within the organization. These tensions may not be between defined organizational units but expressed through high functioning and multidisciplinary teams. In such organizations both business and engineering (as well as other entities) represent their credos and negotiation between entities is ongoing since no one view predominates. Thus goals, particularly in early stages of a project or organizational change, remain fluid and dialog is key to progress (Duhigg 2016). An example, increasingly being adopted by traditional businesses (Power 2014), are lean startup models (Blank and Dorf 2012). In such companies tensions are framed as hypotheses which are then tested and the resulting data drives decision making. In this model tensions both produce new hypotheses and thus growth, but also define the role of the organization. Clearly not all tensions are productive, and may in some cases be destructive, but heavily siloed organizations that lack productive dialog between units with different credos tend over time towards stasis and inefficiency.

In summary, the predominant finance-driven narrative has imbalanced the engineering—business nexus and increasingly focused engineering education on concrete, utilitarian outcomes. This model produces students less able to articulate engineering credos and who are less effective in navigating organizations or contributing to their future direction. Less development of the complex individual produces engineers who are less able to articulate their own credos or those of the engineering profession. The result is an increasing commodification of engineering (Heywood 2014b). Engineering education has a role and responsibility to promote dialog and values if engineers are to play more than an ancillary role in organizations and societies.

21.8 The Path Forward

This chapter has argued that tensions are necessary to organizations if they are to remain agile and not be dominated by one set of values. In the context of the engineering—business nexus this means that engineers should develop an ability to articulate and defend engineering credos within their organization. Education thus needs to prepare graduates able to utilize both Theory X_T and Theory Y_T models of change; i.e. a complex education. The challenge for engineering education is to develop such complex thinking within tight time and content constraints. This section addresses the mandate for change, what that change should be, and how change might be implemented, outlining possible paths forward for engineering education in the evolving engineering—business nexus.

The first question to address is why change is needed. An argument can be made that there is no real need to substantively change engineering programs since by most metrics engineering graduates have among the greatest lifetime return on investment (Carnevale et al. 2011; Taylor et al. 2011) of any degree. If one judges purely by the market, the practice of focusing on the real part of the curriculum has been successful and should be continued if not strengthened. This argument assumes, however, that the overall environment—including K-12 education, universities, and business—is static and past practices will be effective in the future. As discussed above, evidence indicates that the workforce of the twenty-first century will be considerably different than that of the twentieth, and that these changes require complex workers (Clough 2004). These workplace trends are driven by globalization and technology which have brought the world closer together so that engineers are increasingly affected by events external to their organization. This trend also means that engineers' work can have a larger impact on the world at large, placing additional emphasis on the moral responsibility implied by engineers' ethical codes (Kallenberg 2013).

The second question concerns the form of change. As discussed previously the education of engineers focuses on technical and professional skills designed to help graduates be more effective upon joining an organization. While these programs produce graduates that may appear more qualified for immediate transition to the workforce, in the long run they result in a commoditization of engineering (Heywood 2014b) which imbalances the engineering—business nexus. The Theory X_T model is driven by the predominant narrative discussed in the previous section. This narrative has been crafted, in part, by business. For example the 1971 "Powell Manifesto"–written by Lewis Powell to the US Chamber of Commerce several years before his appointment to the US Supreme Court—outlines a comprehensive strategy for promoting the values and interests of the business community in higher education (Powell 1971). The Powell Memo served as a focal point for Theory X_T change models and stimulated significant activity in promoting business values.

The changes needed to balance the engineering—business nexus are for engineering education to undertake similar efforts such as explicitly identifying and developing the credos of engineers, creating uniquely engineering narratives, and shifting engineering curricula towards Theory Y_T models. Engineering credos at the undergraduate level are currently more implied than explicit. Although there have been recent changes at the freshman level, most students' first exposure to engineering is through math and science. The engineering-specific narratives that have been developed mostly focus on better communicating the value of engineering to the public or encouraging participation in STEM education (Committee on Public Understanding of Engineering Messages 2008) rather than frame how engineering credos support social systems and how engineering defines moral good. Student exploration of beliefs and self-narrative needs to include personal experiences in order to develop a credo in dialog with peers and mentors.

The third question is how to implement such changes in programs driven predominately by linear models of learning? While there are many possible models for developing complex engineers the one presented here stems from the mathematician, philosopher, and educator Alfred North Whitehead (Whitehead 1932). Whitehead was concerned with the tendency for education to become a "dry wasteland" of fact, ordered truth and information that was valued for its own sake rather than a means to some greater end for humankind. To make learning vital and living Whitehead proposed education should proceed in three successive, cyclical stages: romance, precision, and generalization.

In Whitehead's model the first stage of education is that of romance. Here the role of education is to show possibility and connection with the mental world inside the student which corresponds to the Y_T or "imaginary" part of the complex learner. Whitehead's second stage is that of precision, corresponding to X_T, where students acquire a "mental grammar" they can use to explore in depth and precision the ideas that were organized apprehended holistically in the stage of romance. The third stage is that of generalization where the broad apprehension of romance is synthesized with the deep understanding of precision, developing the complex learner. Whitehead makes it clear that romance must precede grammar and grammar precede generalization if learning is not to be sterile. Thus romance generally occurs in one's early education, precision during adolescence, and generalization occurs in a university education. This sequence is not rigid, however, since each new thing learned goes through this sequence and if romance is lost learning once again becomes sterile and rote. The stage of romance is particularly important for engineering since historically it has not been taught in primary or secondary schools (Heywood 2014a).

While engineering education has generally done well on the stages of grammar and generalization, the tendency to interpret student development from a Theory X_T perspective undervalues romance and limits the development of engineering credos. Stated more simply, engineering education focuses on "what" and "how" questions, neglecting the "why". Under-emphasis of romance is supported by policies such as ABET's requirement of 1 year of science and math which result in overly focusing on grammar early in students' education. Engineering courses could learn much from art, design, or the social sciences where introductory courses often seek to develop a sociological imagination: "the vivid awareness of the relationship between personal experience and the wider society" (Eisner 1979; Mills 1959). Developing an engineering imagination might focus on technological literacy in relation to key ideas from various engineering credos such as the centrality of human safety and well-being (Kallenberg 2013), conceptions of quality (Pirsig 1974) in physical artifacts, the role of heuristics and evolving state of the art (Koen 2010), and contingency-based reasoning (Goldman 2004). Students could explore how these credos (mis) align with those of other disciplines such as business that may focus more on customers and market performance.

Given the content requirements of most engineering curricula it will be difficult to carve out time for romance from grammar. Technology, however, is increasingly letting learners focus on grammar independently, something all learners must continue to do over the course of their career. Whitehead makes a powerful argument against focusing on the real part of the curriculum without first relating it to the student's life (Whitehead 1932):

> Passing now to the scientific and logical side of education, we remember that here also ideas which are not utilised are positively harmful. By utilising an idea, I mean relating it to that stream, compounded of sense perceptions, feelings, hopes, desires, and of mental activities adjusting thought to thought, which forms our life.

Engineering education has focused significant resources in the last decade on the state of generalization, hoping to develop the complex engineer. These efforts include introducing more projects earlier in the curriculum (Sathianathan et al. 1998), reforming capstone design (Froyd et al. 2012), engaging students in engineering-related service activities (Coyle and Jamieson 2000), and similar programs that seek to integrate engineering with life experiences. In many such programs students work with those from other majors in a mode more related to Theory Y_T. However valuable these opportunities to let students do engineering are, they would be more effective with a more explicit focus on Y_T or romance early in the curriculum to develop beliefs, attitudes, and values as well as how to articulate them.

Another potential value of such integrative programs is to build and maintain community. Community plays a critical role in education and the development of credos (Chambliss and Takacs 2014). A university is not one community but many, and most students belong to several during their time at a university. However if students are to engage with the curriculum, to develop an identity around becoming an engineer, then they need to develop personal connections to a community centered on engineering. In the domain of engineering these include student professional societies, Maker Spaces, Engineers Without Borders, and other affinity groups. Undergraduate research programs that connect students with faculty or graduate student mentors also support Y_T elements of the curriculum as do the small classes and discussion groups common in liberal arts courses.

21.9 Conclusions

This chapter argues that tensions define organizations and societies. The first sections highlight that engineers often adopt a problem-focused mentality when many difficult issues are better framed as tensions. Building from McGregor (1960) two models of addressing issues were introduced. Theory X_T articulates organization goals and uses organizational resources to achieve those goals. From this perspective tensions often interfere with achieving goals, and thus can be seen as leading to dysfunction and stasis. Theory Y_T posits an organizational ecosystem in which the diversity of perspectives, interdependence, and flow of information both define the organization and let it adapt to a changing environment. Tensions are only constructive and generative, however, if individuals and groups have well-articulated credos and sufficient experience interacting with others that the value and worth of the person is maintained despite differences in opinion. Organizations and individuals adopt both perspectives as they try to negotiate between diverse perspectives and converging to an achievable set of goals.

Engineering education should better support individual students in developing engineering credos, i.e. become a "complex engineer". Developing these credos is difficult in a Theory X_T curriculum due to the individual, personal nature of such learning. From a Theory Y_T perspective, however, complex engineers are needed to create productive tensions with the belief systems of business and keep the engineering—business nexus balanced. Such balance is a key question for the engineering profession in the twenty-first century given evidence that a shift towards financialization has contributed to personal harm which violates the ethical canons of engineering and that engineering firms have been complicit in this shift. The complex curriculum also supports the shift to diverse engineering design teams.

Engineering education has a responsibility to produce graduates whose credos articulate engineering as a moral good. To transition engineering education from the dominant Theory X_T perspective to include more elements of Theory Y_T systemic change is needed. Drawing on paradigms such as Whitehead's rhythm of education and adopting elements of liberal arts it may be possible to develop more complex engineers. Such programs will better support the engineering—business nexus and equip students to better navigate the existing tensions they will encounter as they move into the workforce in any capacity.

References

American Society of Civil Engineers. (2013). *2013 report card for America's infrastructure*. Retrieved June, 2016, from http://www.infrastructurereportcard.org/

Argote, L., & Ophir, A. R. (2002). Intraorganizational learning. In J. A. C. Baum (Ed.), *The Blackwell companion to organizations*. New York: Wiley-Blackwell.

Aristotle. (n.d.). *Nichomachean ethics*, book VI, ch. 4 (1140A1-23) (D. Ross, Trans.). Oxford: Oxford University Press.

Aubert, V. (1963). Competition and dissensus: Two types of conflict and of conflict resolution. *Conflict Resolution, 7*(1), 26.

Bartha, P. (2013). Analogy and analogical reasoning. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. Retrieved from http://plato.stanford.edu/archives/fall2013/entries/reasoning-analogy/

Blank, S., & Dorf, B. (2012). *The startup owner's manual: The step-by-step guide for building a great company*. Pescadero: K & S Ranch.

Bruner, J. (1987). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Buber, M. (2010). *I and Thou*. Eastford: Martino.

Bucciarelli, L. (1996). *Designing engineers*. Cambridge, MA: The MIT Press.

Burns, T. (1966). On the plurality of social systems. In J. R. Lawrence (Ed.), *Operational research and the social sciences*. London: Tavistock.

Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM*. Washington, DC: Center on Education and the Workforce, Georgetown University.

Cech, E. A. (2013). Culture of disengagement in engineering education? *Science Technology Human Values, 39*(1), 34–63.

Chambliss, D. F., & Takacs, C. G. (2014). *How college works*. Cambridge, MA: Harvard University Press.

Cheville, R. A. (2014). *Defining engineering education*. Paper presented at the American Society for Engineering Education, Indianapolis, IN.

Cheville, R. A. (2016). Linking capabilities to functionings: Adapting narrative forms from role-playing games to education. *Higher Education, 71*, 805–818.

Cheville, R. A., & Heywood, J. (2015). *Drafting a code of ethics for engineering education.* Paper presented at the Frontiers in Education El Paso.

Cheville, R. A., & Heywood, J. (2016). *From problem solvers to problem seekers: The necessary role of tension in engineering education*. Paper presented at the American Society of Engineering Education Annual Meeting, New Orleans.

Clough, G. W., et al. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academy Press.

Committee on Public Understanding of Engineering Messages. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: National Academies Press.

Connolly, M., & Seymour, E. (2012). *Why theories of change matter (Examples from EHR programs)*. Washington, DC: National Science Foundation.

Coyle, E. J., & Jamieson, L. H. (2000). Projects that matter: Concepts and models for service-learning in engineering. In E. Tsang (Ed.), *EPICS: Service learning by design – Engineering projects in community service* (pp. 59–74). Washington, DC: American Association for Higher Education.

Davis, M. (1998). *Thinking like an engineer: Studies in the ethics of a profession*. New York: Oxford University Press.

Dias, P. (2013). The engineer's identity crisis: Homo Faber or *Homo Sapiens*? In D. P. Michelfelder, N. McCarthy, & D. E. Goldberg (Eds.), *Philosophy and engineering: Reflections on practice, principles and process*. Dordrecht: Springer.

Dodd, D., & Favaro, K. (2006). Managing the right tension. *Harvard Business Review, 84*(12), 62–74.

Drucker, P. (1999). *Management challenges for the 21st century*. New York: Harper.

Duhigg, C. (2016, February 25). What google learned from its quest to build the perfect team. *New York Times Magazine,* 20.

Eisner, E. W. (1979). *The educational imagination: On the design of and evaluation of school programs*. London: Collier Macmillan.

Elsbach, K. D. (2002). Intra organizational institutions. In J. A. C. Baum (Ed.), *The Blackwell companion to organizations*. Oxford: Blackwell.

Flaherty, C. (2015 June 26). Watered-down Gen Ed for engineers? *Inside Higher Ed*.

Foroohar, R. (2016). *Makers and takers: The rise of finance and the fall of American business*. New York: Crown Business.

Friedman, M. (1970, September 13). The social responsibility of business is to increase its profits. *New York Times Magazine*.
Froyd, J. E., & Lohmann, J. R. (2013). Chronological and ontological development of engineering education as a field of scientific inquiry. In A. Johri & B. M. Olds (Eds.), *Cambridge handbook of engineering education*. New York: Cambridge University Press.
Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE, 100*, 1344–1360.
Fumasoli, T., Gornitzka, A., & Maassen, P. A. M. (2014). *University autonomy and organizational change dynamics*. Oslo: ARENA.
Giddens, A. (1987). *Social theory and modern sociology*. Cambridge: Polity Press.
Goldman, S. L. (2004). Why we need a philosophy of engineering: A work in progress. *Interdisciplinary Science Reviews, 29*, 163–176.
Grinter Report. (1994). Report on evaluation of engineering education (reprint of the 1955 report). *Journal of Engineering Education, 93*(1), 74–94.
Hale, T., & Viña, G. (2016). University challenge: The race for money, students and status. *Financial Times Magazine*.
Hesseling, P. (1966). *Strategy of evaluation research*. Van Gorcum: Assen.
Heywood, J. (2000). *Assessment in higher education: Student learning, teaching, programmes and institutions*. London: Jessica Kingsley Publishers.
Heywood, J. (2014a). *Designing a stage of "romance" for programs in technological literacy*. Paper presented at the American Society of Engineering Education Annual Conference, Indianapolis.
Heywood, J. (2014b). *Who am I? Who are you? Where are we going?* Paper presented at the Frontiers in Education, Madrid.
Holton, E. F. (Ed.). (1998). *Preparing students for life beyond the classroom*. San Francisco: Jossey-Bass.
James, W. (1912). *The will to believe and other essays in popular philosophy*. New York: Longman, Greens, and Co..
Johnson, D., & Johnson, R. (1993). *Cooperative, competitive, and individualistic procedures for educating adults: A comparative analysis*. Duluth: University of Minnesota: Cooperative Learning Center.
Johnson, D. W., Johnson, R. T., & Smith, K. A. (2000). Constructive controversy: The educative power of intellectual conflict. *Change, 32*(1), 28–37.
Jones, E. A. (2002). *Transforming the curriculum: Preparing students for a changing world*. ASHE-ERIC Higher Education Reports.
Kallenberg, B. J. (2013). *By design: Ethics, theology, and the practice of engineering*. Eugene: Cascade Books.
Kezar, A. J. (2001). *Understanding and facilitating organizational change in the 21st century: Recent research and conceptualizations*. ASHE-ERIC Higher Education Report.
Koen, B. V. (2010). Quo Vadis humans? Engineering the survival of the human species. In I. van de Poel & D. Goldberg (Eds.), *Philosophy and engineering: An emerging agenda*. New York: Springer.
MacMurray, J. (1961). *Persons in relation*. London: Faber & Faber.
Mann, C. R. (1918). *A study of engineering education*. Boston: Carnegie Foundation for the Advancement of Teaching.
Margolis, E. (2001). *The hidden curriculum in higher education*. New York: Routledge.
McGregor, D. (1960). *The human side of enterprise*. New York: McGrawHill.
McKinney, K., & Heyl, B. S. (2009). *Sociology through active learning: Student exercises*. Thousand Oaks: Pine Forge Press.
Meadows, D. H. (2002). Dancing with systems. *The Systems Thinker, 13*(2), 2–6.
Meadows, D. H. (2008). *Thinking in systems: A primer*. White River: Chelsea Green Publishing.
Mentkowski, M. (1999). *Learning that lasts: Integrating learning, development, and performance in college and beyond*. San Francisco: Jossey-Bass.
Meyerson, D. E. (2001). *Tempered radicals: How people use difference to inspire change at work*. Cambridge, MA: Harvard Business School Press.

Mills, C. W. (1959). *The sociological imagination*. Oxford: Oxford University Press.
Newman, J. H. (1852). *The idea of a university defined and illustrated: In nine discourses delivered to the catholics of Dublin*. Project Gutenberg.
Pawley, A. L. (2009). Universalized narratives: Patterns in how faculty members define "Engineering". *Journal of Engineering Education, 98*, 309–319.
Percy, L. E. (1945). *Report of the special committee on higher technological education*. London: H. M. Stationery Office.
Pfeffer, J., & Sutton, R. I. (2000). *The knowing-doing gap: How smart companies turn knowledge into action*. Boston: Harvard Business School Press.
Pirsig, R. M. (1974). *Zen and the art of motorcycle maintenance*. New York: Harper-Collins.
Powell Jr., L. F. (1971). Confidential memorandum: Attach on American free enterprise system: U.S. Chamber of Commerce.
Power, B. (2014, April 23). How GE applies lean startup practices. *Harvard Business Review*.
Reich, R. B. (2016). *Saving capitalism for the many, not the few*. New York: Alfred A. Knopf.
Rogers, K. J. (2015, September 1). A work in progress. *Inside Higher Ed*.
Rokeach, M. (1968). *Beliefs, attitudes, and values: A theory of organization and change*. San Francisco: Jossey-Bass.
Sathianathan, D., Sheppard, S., Jenison, R., Bilgutay, N., Demel, J., Gavankar, P., Lockledge, J., Mutherasan, R., Philips, H., Poli, C., Richardson, J. (1998). *Freshman design projects: Lessons learned in engineering coalitions*. Paper presented at the Frontiers in Education, Tempe, AZ.
Schein, E. H. (1992). *Organizational culture and leadership* (2nd ed.). San Francisco: Jossey Bass.
Schiro, M. S. (2012). *Curriculum theory: Conflicting visions and enduring concerns*. Thousand Oaks: Sage.
Seely, B. E. (1999). The other re-engineering of engineering education, 1900–1965. *Journal of Engineering Education, 89*(3), 285–294.
Sen, A., Muellbauer, J., & Hawthorn, G. (1987). *The standard of living*. Cambridge: Cambridge University Press.
Senge, P. (2006). *The fifth discipline: The art & practice of the learning organization*. New York: Doubleday.
Silverthorne, S. (2011). *The most important management trends of the (still young) twenty-first century*. Working Knowledge, Harvard Business School. Accessed at: http://hbswk.hbs.edu/item/the-most-important-management-trends-of-the-still-young-twenty-first-century
Slaton, A., & Riley, D. M. (2015, July 8). The wrong solution for STEM education. *Inside Higher Ed*.
Stroh, D. P. (2015). *Systems thinking for social change: A practical guide to solving complex problems, avoiding unintended consequences, and achieving lasting results*. White River Junction: Chelsea Green Publishing.
Taylor, P., Parker, K., Fry, R., Cohn, D., Wang, W., Velasco, G., & Dockterman, D. (2011). *Is college worth it? College presidents, public assess value, quality and mission of higher education*. Washington, DC: Pew Research Center.
Trevelyan, J. (2014). *The making of an expert engineer*. London: CRC Press.
Turner, A. (2015). *Between debt and the devil: Money, credit, and fixing global finance*. Princeton: Princeton University Press.
Unsworth, K. (2001). Unpacking creativity. *Academy of Management Review, 26*(2), 289–297.
Vinck, D. (Ed.). (2003). *Everyday engineering: An ethnography of design and innovation*. Cambridge, MA: MIT Press.
W. K. Kellogg Foundation. (2004). *Logic model development guide*. Battle Creek: W. K. Kellogg Foundation.
Whitehead, A. N. (1932). *The aims of education and other essays*. London: Benn.
Wilson, T. D. (2011). *Redirect: The surprising new science of psychological change*. New York: Little, Brown, and Company.
Woods, D. R. (1996). *Problem-based learning: How to gain the most from PBL* (3rd ed.). Hamilton: Waterdown.

R. Alan Cheville BS and PhD in Electrical Engineering, Rice University. Professor and T. Jefferson Miers Chair of Electrical and Computer Engineering at Bucknell University, Lewisburg, Pennsylvania. While a faculty member at Oklahoma State University worked terahertz optoelectronics and engineering education, developing resources in photonics and engineering design. After serving for 2.5 years as a program director in engineering education at the National Science Foundation, he took a chair position in the Electrical & Computer Engineering Department at Bucknell University. He is currently interested in engineering design education, engineering education policy, and the philosophy of engineering education. He serves as associate editor for IEEE Transactions on Education and the Journal of Engineering Education as well as serving on several national-level advisory boards. As chair of the Department of Electrical and Computer Engineering he has been active in curriculum reform efforts.

John Heywood He holds a higher doctorate from Trinity College. He is a Life Fellow of the American Society for Engineering Education, and the Institute of Electrical and Electronic Engineers, and an Honorary Fellow of the Institution of Engineers Ireland. His research interests are in engineering education, its philosophy, curriculum and instruction. He came to Trinity College Dublin, where he was Professor of Teacher Education, from the Faculty of Engineering of Liverpool University where he lectured in industrial studies and management. Prior to that he conducted research at Lancaster University into examinations and assessment, and designed new models of assessment for engineering science in schools. In the 1970s he directed the first major study of engineers at work for the purpose of determining objectives for training technologists and technicians. His 2005 award winning book, *Engineering Education. Research and Development in Curriculum and Instruction* is one of the ikons of the multi-million dollar development of engineering education as field of scientific inquiry in the United States. He has over 100 publications and his most recent book *The Assessment of Learning in Engineering Education. Practice and Policy* was published earlier this year. An additional book *The Human Side of Engineering*” is in the press.

Chapter 22
Employability in Engineering Education: Are Engineering Students Ready for Work?

Anette Kolmos and Jette Egelund Holgaard

Abstract International professional organisations, including accreditation bodies, have stressed that a so-called skill-gap between engineering education and work exists, which increases the focus on employability in engineering education research. In this chapter, we propose a comprehensive definition of employability that combines scientific and domain specific engineering skills with process competences and a concern to the business and societal context in which engineering work is embedded. From that point of view, we set out to study which skills students find important to be employable, whether this perception of importance varies over time, and also which skills the students think they have actually achieved during their study. We draw on data provided from the project research project PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark (2009–2013)) and the follow up project PROCEED-2-Work, where the latter has a specific employability perspective. Data have been collected through a survey handed out to all Danish engineering students enrolled in 2010, and data was collected in 2010, 2011 and as a part of PROCEED-2-Work in 2015. The results show a kind of instrumental turn in what students think matters in engineering work throughout their study, and a general lack of attention to more contextual factors. The chapter concludes with a discussion about potential pillars of change with a more comprehensive view on employability.

Keywords Employability · Student perspective · Process competences · Contextual knowledge

---

A. Kolmos (✉)
Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability, Aalborg University, Aalborg, Denmark
e-mail: ak@plan.aau.dk

J. E. Holgaard
Department of Development and Planning, Aalborg University, Aalborg, Denmark
e-mail: jeh@plan.aau.dk

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*, Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_22

22.1 Introduction

During the late 1990s, employability was on the political and educational agenda. Politically the Bologna process in the EU was starting to be formed with an emphasis on outcomes, skills and competences, and on bridging the gap between education and work, and accreditation bodies like ABET and EUR-ACE started to formulate skills relevant to the work situation (ABET 1995, 2006; Bourgeois 2002; Engineering Council UK 2004; Engineers Australia 2006; EU Commission 2008). Since the 1990s, the political importance of employability in engineering education has grown and the latest political initiative in Denmark (DK) involves a degree of employability for various programmes as a factor for resources to education. The Bologna process and some of the EU Commission communiques actually stress some new skills like entrepreneurship and creativity as important skills to learn in education. The political interest in employability seems, however, not so much to be about what kind of skills and competences students should learn at university, but mostly that the skills and competences students have achieved will lead to employment.

For years, international professional organisations with an interest in engineering education have identified a major problem between education and work and characterised this problem as a skills gap. The latest McKinsey report indicates that we are far from creating bridges between work and education (Mourshed et al. 2012). Also reports from the Royal Academy, UK points at similar problems that the graduates are not able to go straight into a job and work, but that companies and organisations have to invest in this transformation process. For example, the Henley report concludes that employers are not really satisfied with graduates and that there is a shortage of skills and a later Royal Academy report analyses possible ways to change the curriculum to prepare students better for the work situation (Lamb et al. 2010; Saeki and Blom 2011; Spinks et al. 2006). However, this is a world-wide problem, and another example is to be found in a World Bank study, which emphasises that more than 60% of the employers in India hiring new graduates are not satisfied with the prior training and they have to invest heavily in getting the new engineers ready for work (Saeki and Blom 2011). Seen from both an employer and societal point of view, this is an unsatisfactory situation.

22.2 Research Question and Methodology

This article will present findings from PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark) carried out from 2009 until 2013 and the follow-up study PROCEED-2-Work, which together constitute a longitudinal study where data has been collected twice in the first year and in the final year of an engineering study. The research questions for this article are: Which skills do students find important to be employable and does the importance vary over time? And which skills do students think they actually have achieved during their study?

The purpose is threefold. First of all, we want to point to potential diversity in the way students perceive preparedness. Secondly, we want to point to the pedagogical means that students find effective in preparing them for working life. Third and last, we want to discuss the potential implications of students' perceptions of pedagogical means for what and how we teach for employability.

Theoretically, we draw on a literature review to gather a comprehensive understanding of employability skills and relate to different types of knowledge and curriculum strategies. Empirically, we draw on the longitudinal study of students in three stages of their development process: entering university, after the first year of study and finalising their study. Surveys have been carried out in 2010, 2011 and 2015 with more than 1000 respondents from different Danish Engineering institutions.

22.3 Understanding of Employability and Employability Skills – A Literature Review

What is employability and what kinds of skills are important to learn in education for students to be employable? Most researchers underpin the complexity in the employability agenda and some even warn that academia and the graduates are becoming too instrumental in their learning approach (Moreau and Leathwood 2006). Although with a critical stance, the most commonly used definition of employability is the one by Peter Knight and Mantz Yorke (2003):

> a set of achievements, understandings and personal attributes that make individuals more likely to gain employment and be successful in their chosen profession. (Knight and Yorke 2003, p. 5)

Later on Yorke (2004, p. 3) modifies this definition to:

> a set of achievements – skills, understanding and personal attributes – that makes graduates more likely to gain employment and be successful in their chosen occupation, which benefits themselves, the workforce, the community and the economy. (Yorke 2004, p. 3)

In both definitions, the focus is on the individual's ability to meet the requirements. However, the intention of the revised version is to stress that employability does not only apply to the employer, but in broader terms to individuals themselves, the workforce instead of the employer, the community, and the economy. This is a much broader approach to employability than the one normally applied, which according to the BusinessDictionary has a more narrow scope and contains the essential abilities necessary for success in the workplace (BusinessDictionary 2016). We proceed with the revised understanding of employability, which leaves room for a much broader understanding of employability, picturing the employed as a citizen and as a member of society who is able to make a sustainable living.

Furthermore, to understand employability in a more theoretical framework, Knight and Yorke have identified four interlocking elements: understanding of the subject in relation to employability, skilful practice in context, efficacy beliefs, and metacognition (Yorke 2004). With this approach, they link academic knowledge, skills, reflection and personal attitudes, which gives a much more holistic view of the learner and the educated citizen.

22.3.1 Research on Employability Skills

There are quite different approaches to researching employability. What most studies and definitions agree on is that employability implies the learning of skills and competencies, which is nothing new in the educational debate, but part of the outcome-based education trend. The question is what kind of skills and competencies characterise the employability discourse and which stakeholders formulate the needs?

In general, when reviewing the employability literature, the conceptualisation of employability skills is very diverse and the overall concepts are also overlapping. In the early conceptualisations of employability skills, terms like transferable skills, key skills, core skills, and generic skills were used. The term transferable skills indicates that skills can be transfered from the learned area to new areas (Assiter 1995), whereas key and core skills are understood much more as the most important skills for employability and students' experience (Dunne et al. 2000; Fallows and Steven 2000). The term generic skills was also used and Peter Kearns (2001), in particular, analyses the different ways generic skills are approached. In the US, generic skills are conceptualised in a much broader way compared to the UK. Based on these analyses, Kearns concludes that there is no international consensus on defining specific employability skills and none so ever on how to organise the students' learning (Kearns 2001).

Similar non-consistencies exist in the definition of employability skills. Imren Markes has made a review of the literature on employability skills in engineering (Markes 2006). For each of the 22 studies reviewed, there is a separate list of specific employability skills. Markes concludes that there is no right way to define the specific employability skills, but the skills have to be defined by the contextual issues. Different stakeholders, representing both industrial and professional organisations, carried out the 22 studies. Across these studies communication, teamwork, problem solving, and management seem to be the most dominant skills.

Alex Tymon has made a similar study, however with only six studies and not from engineering. In his analysis of the studies, he finds communication, teamwork and interpersonal skills as the most dominant among the specific skills (Tymon 2011).

The scope of employability skills is very broad, as the skills agenda has been taken over at the political level to make sure that there is implementation at the university level. In various countries, therefore, there have been attempts to define a framework of "employability skills". An Australian study analysed the development of the discourse from the Australian key-competence framework to new formulations under the heading of employability skills. This study found that the personal attributes possess a more dominant status and made the recommendation to integrate elements into higher education although this might not be easy for any assessment (Williams 2005).

The literature shows no consistent set of employability skills – on the contrary, the specific employability skills will have to be constructed according to the context and by that according to the stakeholders. Several researchers also underpin that the understanding and the scope of employability skills will be dependent on a stakeholder perspective: government, employer, graduate, higher education institution, wider society, and students (Tymon 2011). All stakeholders have different interests in the qualification of the workforce. Although, there seems to be a common agreement on communication, teamwork, management and problem solving, these skills have been formulated for a long time under other headings such as generic skills and transferable skills.

22.3.2 Employer Requirements

There is a set of studies on employers' formulation of needed skills. Many of these studies link to the requirement for engineering education and tend to be more a mapping of wishful thinking than actually a study of what would be needed in the workplace as core knowledge, skills and competencies. Many of the studies ask employers what they want with the possibility to want more of most skills, and the results are often unsurprising, as employers want more of everything. In some Danish studies the results were that employers expressed the wish that graduates have more understanding of business models, project management and communication (Kolmos and Holgaard 2010). These results are in line with other studies, like a British study on recruitment where employers were much more interested in attitudes, personality and transferable skills than the type of subject and educational level. Motivation, IT skills, teamwork and willingness to learn gain the top scores among long lists of what employers look for (Branine 2008). In line with the emphasis on employability skills, a UK study analysed 1000 job advertisements, and communication was mentioned most often followed by IT, organisation and teamwork (Bennett 2002).

An Australian study compared employers' and students' views on skills and found that many of the "so-called" employability skills in fact are to be regarded as life skills and that employers were rather looking for these skills rather than subject skills; however, the young students expected the subject skills to be the most important (Taylor 2005). The comparison between what students expect and what employers wish for is quite interesting, and the comparison perhaps says more about the higher education curricula as students have to react to the curriculum in order to pass their exams.

22.3.3 Transition from Education to Work

Another cluster of studies focuses on the transition from education to work mostly based on data from graduates. In Sweden, there are a substantial number of studies with the aim to identify transition issues. Staffan Nilsson reports a study based on qualitative interviews with 20 recently graduated engineers (Nilsson 2010). His study reveals the same pattern in that the graduated engineers find that the most important aspect of successful functioning in the job are the transferable and meta-cognitive skills and an ability to adjust to context and situations. The graduates subsequently also think that the engineering programmes are too focused on subjects and miss out elements of learning employability. Furthermore, the study indicates that the graduates experience that the transition is highly dependent on the individual's readiness to change and is seen as an individualised responsibility.

Another Swedish qualitative study comes up with other results indicating that the engineering graduates actually value the technical professional aspects together with the employability skills (Stiwne and Jungert 2010). This study also indicates that the best way to integrate employability into the education is by company projects where students learn to apply their academic knowledge on concrete problems and experience the work environment or by co-curricular activities, which are often more open and problem-oriented compared to the traditional curriculum.

A US study reports considerable differences in how three different stakeholders regard employability: the graduates, the academic staff educating them and the human resource managers who recruited them (Rosenberg et al. 2012). The three stakeholder groups had diverse views on the skills needed for the job, the skills learned in education and the additional need for training. For almost all skills, the graduates score higher compared to the two other groups, whereas for training needs, the graduates score lower for most training factors. The purpose of this study is to investigate how educational designers can foster a more meaningful construction of employability skills during education.

Yorke (2004) reports studies in the UK on graduates' perception of employability elements in the curricula (Yorke 2004). Graduates across five different subject areas (biology, business, computing, design and history) find that academic staff gave subject knowledge the highest priority, and business awareness and practical workplace experience scored the lowest among a long list of factors. The same pattern is repeated when asking graduates to what extent they experienced that their educational institution has helped them to develop their employability skills. Building up networks, understanding clients' needs and intercultural understanding are among the lowest scores.

Madeleine Abrandt Dahlgren et al. (2006) has conducted a study on transition issues by regarding the transition as a trajectory between two different communities. Applying the community of learning theories opens quite a different aspect of employability such as identity and knowledge formation. The study compares graduates from three different programmes, of which one programme is from engineering. Each programme corresponds differently with work requirements experienced by the graduates. For engineering, the findings illustrate that elements in the curriculum that should lead to identity and professional knowledge formation could be characterised more as ritual than actually corresponding to the needs of the work situation (Dahlgren et al. 2006).

No matter which study is reported, there seems to be evidence for a gap between, on the one side, academic staff and the curriculum and on the other side graduates' experiences, which match the experiences of the employers.

In Denmark, we have not systematically documented the transition from engineering education to working life, and the existing PROCEED-2-WORK project is one of the first projects studying a systematic transition from education to work. There have been a number of alumni studies where an institution surveys its own candidates, which is permeated with many critical methodological issues as graduates most likely will respond positively to their own institution. In Denmark, there is an empirical need to clarify the transition issues from education to work in line with the documented skill gaps in other countries.

22.3.4 Academic Staff Perspective

There are a few studies on how academic staff view employability or so-called work related learning. A Swedish study actually showed that academic staff are relatively positive towards employability issues in the curriculum and that especially academic staff with work experience outside university are more positive compared to staff with no experience outside university (Magnell et al. 2014). Other findings from the study are that academic staff rate critical thinking, problem solving, new solutions and technical knowledge as the most important knowledge, skills and competences in the engineering profession, which is in contradiction to what employers and graduates report. So even if there is a positive attitude towards integrating work-related issues, the understanding of what this will involve might not be consistent.

22.3.5 Students' Approach to and Learning of Employability

While there are quite a substantial number of studies identifying employers' requirements, and identifying the gaps between education and work in responses from graduates, there are very few research studies on students' approach to and learning of some of the employability skills. In the literature, the learning of employability skills is mostly covered by either what graduates report back to education or reflections based on curriculum and learning theories (Knight and Yorke 2004). However, surveying the students for their priorities or their learning of orientation to the working life is lacking. As this review points out, there are differences in the stakeholder approaches to the learning of skills and no matter what the curriculum tries to emphasise, the learning will in the end be determined by the students. Of course, students react to the formal curriculum and in many ways they will mirror the priorities in the curriculum, as this is what they have been examined in. But as a stakeholder group, the students have mixed interests – on the one side they would like to meet academic criteria and on the other side they would like to have a job afterwards and therefore they have an interest in attaining the relevant knowledge and skills to work outside academia also.

Michael Tomlinson conducted a qualitative study on final year students' views on the coming requirements from work. The results from this study were that students expect their academic qualifications to have importance, but they also do voluntary work outside university for adding value to the academic competencies (Tomlinson 2008). Similar studies conclude that the students' priority of employability increases as their studies progress (Moreau and Leathwood 2006).

Tymon (2011) has conducted a longitudinal study of business students to uncover their view on which transferable skills might be necessary for the later work situation (Tymon 2011). Data was collected in the first, second and final year. The general findings in this study were that during the first year, the students found that employability matters more and that the students' confidence in expressing themselves increased. The students also found that internship was the most efficient way to learn about employability as well as teamwork, etc. To the questions on what employability means to the students, the results were very much in line with the other studies. The students emphasised communication, teamwork, management, IT skills together with some more personal attributes like flexibility, hardworking, etc. Tyler also concludes that there was less alignment between the broader scope of employability and concludes that the students are most concerned with the more narrow – economic and instrumental – view of employability (Tymon 2011).

22.4 What Students Think Matters in Engineering Work – And the Matter of Preparedness

As the literature indicates, the employability agenda is complex and determined by the stakeholders. There are empirical studies available but the literature review also reveals a need for more theoretical and methodological development. The complexities surrounding the relationship between work and education are high and there is a need for both theoretical understanding as well as more research in the area – also to understand what transfer and transition is about by crossing existing institutional and contextual boundaries between education and work (Akkerman and Bakker 2011; Dahlgren et al. 2006; Konkola et al. 2007). The students' perspective on employability is less analysed compared to graduates' and employers' perspectives.

The research project PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark (2009–2013)) is, however, one example of a study with a student perspective on engineering skills, which was followed up in 2015 with PROCEED-2-Work, with a specific employability perspective. In a subproject of PROCEED, a survey was handed out to all engineering students enrolled in 2010, and data was collected in 2010 and 2011. In the PROCEED-2-Work project, a follow-up survey was made in order to have a longitudinal perspective on the way education framed students' understanding of engineering and their sense of preparedness, as they are about to move into the workplace.

The findings presented in this chapter are based on frequency analysis. The number of respondents (N) is related to the respondent rate to a specific battery of questions. In questions where students were asked to rate the top five in regard to skills, just starting the questionnaire would however count as an answer, whereas the percentages of respondents actually selecting the specific item would decrease. In these cases, we have chosen only to account for respondents who have completed the questionnaire.

22.4.1 What Students Think Matters

In studying what students think matters in engineering work, we have used the list of possible items from the Academic Pathways Studies of People Learning Engineering Survey (APPLES) prepared by the Center for the Advancement of Engineering Education, US (ABET 2011; Atman et al. 2010). According to Atman et al. (2010), these items have been developed from the ABET criterion 3 programme outcomes list (ABET 2011) and the National Academy of Engineering report, "The Engineer of 2020" (National Academy of Engineering 2004). The use of this list of items made it possible to compare the Danish responses to the US responses in order to discuss potential similarities and differences across continents. Furthermore, the items cover the intended broad perspective on employability, namely:

- fundamental skills in natural science, including science and maths
- specific engineering skills, including engineering analysis and the use of engineering tools
- process competencies, including problem solving, design, teamwork, creativity, communication, and life-long learning,
- business awareness, including professionalism, business knowledge, leadership and management skills
- contextual skills, including awareness of the societal context, global context, ethics and contemporary issues.

The items are listed in Fig. 22.1 together with the responses from the 2015 survey, where students were asked to rate the five most important items in relation to engineering work.

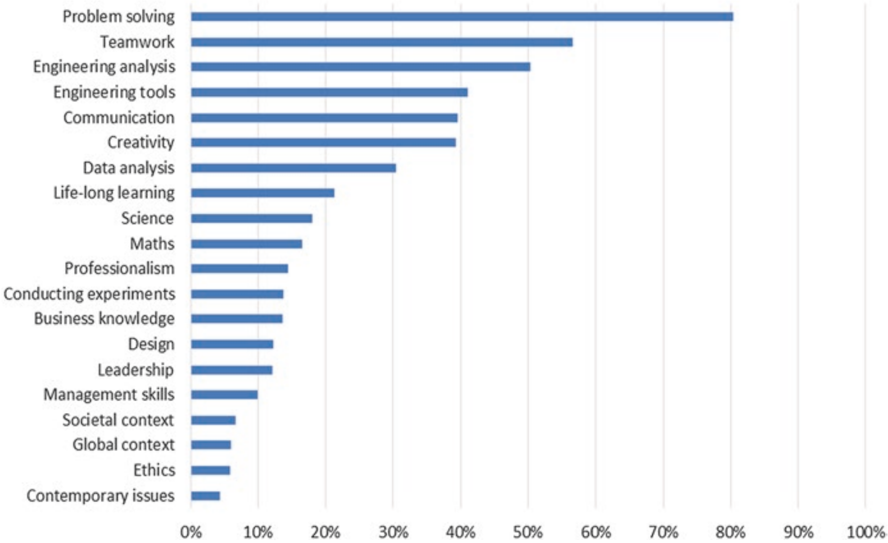

Fig. 22.1 The percentages of students, who have rated the items in the top five of importance for engineering work, N = 878

About four out of five have ranked problem solving in the top five of importance for engineering work – this was also the case for the US survey. Together with creativity, which is rated number 6, it indicates a focus on creating new technology. In both the Danish and the US study, communication and teamwork are highly rated (both in the top five), although the emphasis on communication is higher in the US (65% of students have communication in the top five compared to 40% in Denmark). The focus on problem solving, communication and teamwork corresponds to the cross-cutting skills defined by the different stakeholders in the 22 studies reviewed by Markes (2006). The last cross-cutting skill was management, but as can be seen in Fig. 22.1 management skills are not so highly prioritised by Danish students as less than 10% rate these skills in the top five. In the US study, the results related to management skills are similar (11% marked in the top five).

However, three items are given considerably lower priority in the Danish context compared to the US context. In the US survey, ethics and design are in the top 6 out of the 20 items, where ethics is rated as the fifth and design as the sixth, with respectively 40% and 35% of the students ranking these items in the top five for importance for engineering work. In Denmark, only 12% rate design in the top 5, and for ethics the number is even less (6%) leaving design as number 14 and ethics ranked as number 19 in importance out of the 20 items.

The attention to engineering ethics has been more strongly institutionalised in the US, e.g. through the National Society of Professional Engineering Code of Ethics (National Society of Professional Engineers 2016) and the ABET criteria where it is explicitly stated that ethics together with design are criteria among the 11 listed criteria for students' required learning outcomes (ABET 2014, page 3):

> (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
>
> …
>
> (f) an understanding of professional and ethical responsibility.

In Denmark, the calls for system design and ethics in engineering education are not institutionalised to the same extent.

Furthermore, engineering analysis and engineering tools are among the five most frequently rated skills in the top five of important engineering skills. The focus on engineering tools differs from the US study that rated them considerably lower (rated 11 out of 20 items). Among the five least prioritised skills are, together with management skills as mentioned above, the social and global context, ethics and also contemporary issues. The contrast with the US study lies in the attention to ethics as already discussed. Together with the focus on engineering tools, the lack of attention to contextual factors in the Danish study mirrors the conclusion of Tymon (2011) stating that students are most concerned with the more narrow economic and instrumental view of employability.

22.4.2 How Education Shapes "What Matters"

By surveying students when entering their studies, after the first year and at the end of their studies it is possible to reveal how their perception of "what matters" changes during their educational path.

Figure 22.2 illustrates how the numbers of students prioritising items in the top five have changed during the study. It shows that the educational path has provided a change in what students think is important towards a stronger emphasis on engineering analysis, engineering tools, data analysis and communication; whereas less importance is assigned to maths, science and items related to business awareness and contextual skills. Therefore, the instrumental view on employability is thereby strengthened through higher education.

We furthermore asked students to assess 13 different types of competencies without focusing on domain specific engineering skills, and for each competence students were asked to rate it as not important, somewhat important, very important or decisive for being a successful engineer. Figure 22.3 shows the development in competencies assigned decisive importance for being successful in engineering.

As shown in Fig. 22.3, critical thinking, communication and confidence grew considerably in assigned importance (>10%), whereas maths, the desire to find new solutions and leadership are the only items decreasing (2–6.6%). This indicates that the so-called life skills for employability increased in importance during study,

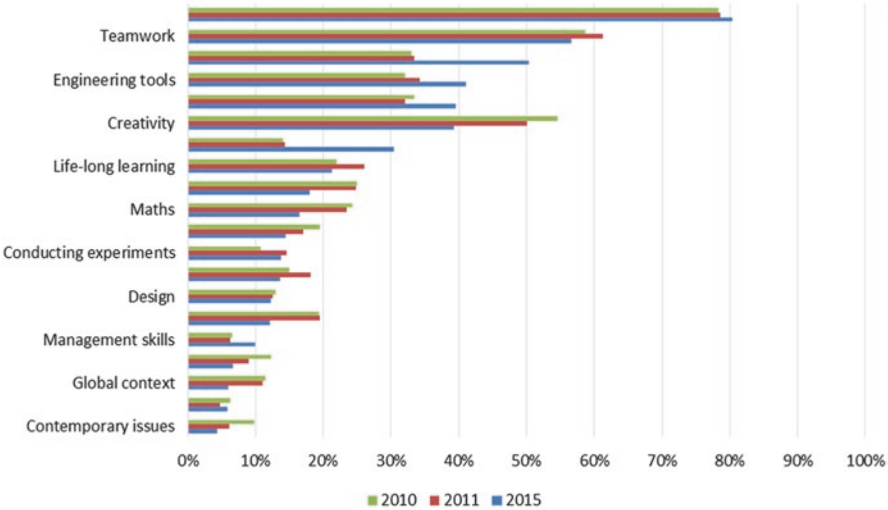

Fig. 22.2 The percentages of students who have rated the items in the top five for importance in engineering work in 2010 (N = 1417), 2011 (N = 1009) and 2015 (N = 878)

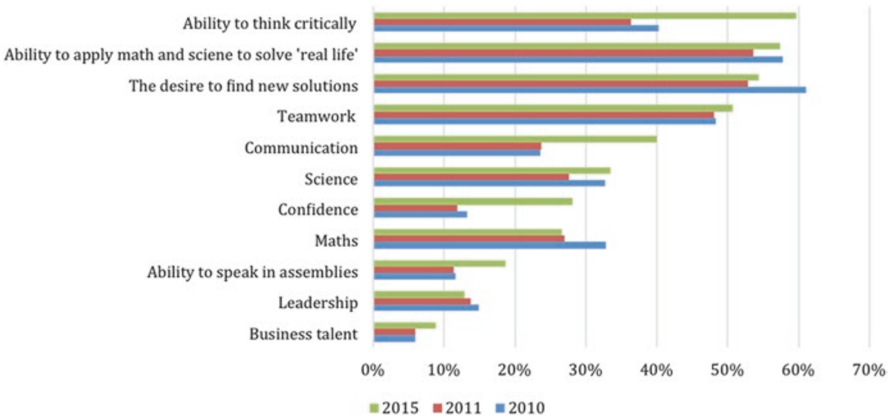

Fig. 22.3 The percentages of students who have rated the items as decisive for engineering, 2010 (N = 1617–1624), 2011 (N = 1116–1121) and 2015 (N = 977–982)

although the change is not visible in the first year when the students have a tendency to rate the importance lower than when they entered study and thereby seem to be questioning the pre-assessed importance assigned when they entered study.

The survey from 2010 to 2011 did not include sustainability in this battery of questions. However, from the 2015 survey we found that 20% of students considered the ability to incorporate environmental considerations as being decisive for engineering, whereas 15% considered social responsibility as such. In comparison 27% of students considered maths to be of decisive importance.

22.4.3 Preparedness of Engineering Students to Enter into Working Life

Anette Kolmos et al. (2016) have reported on the preparedness of students in the final stage of study, just before entering working life based on the 2015 survey (Kolmos and Bylov 2016). The results are illustrated in Fig. 22.4.

The study showed that (Kolmos et al. 2016):

- most students (four out of five) felt very well prepared to face the challenges of teamwork and problem solving;
- more than half of students felt very well prepared to handle engineering tools, professionalism, data analysis, science, maths, conduct experiments and to handle the more generic aspects of creativity and communication;
- More than one out of four students felt not at all prepared to address environmental, impacts, ethics, the global and societal context, contemporary issues as well as design, business knowledge and leadership.

Taking into consideration the low attention to contextual factors (the global and societal context) and contemporary issues, the question is whether the problem solving focus is in fact taking into consideration the problem design process. Problem design includes questions like: where do the problems engineers solve come from, why do some problems draw attention and others not, and how can we get closer to understanding the mechanisms that at one point create the problem and in another context can resolve the problem? (Holgaard et al. 2016). Having the skills

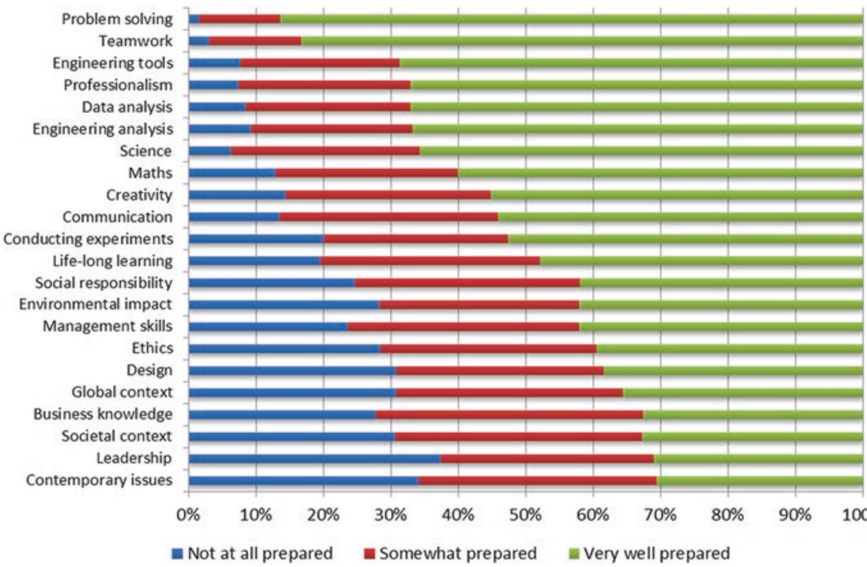

Fig. 22.4 The degree to which students feel prepared to apply the stated items in engineering work, N = 1000–1009 (Kolmos et al. 2016)

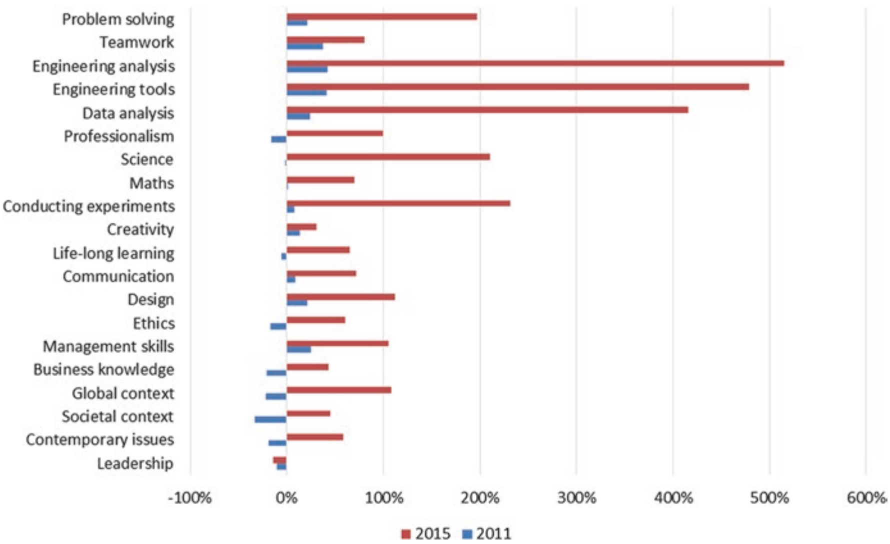

Fig. 22.5 The degree to which students' sense of preparedness has increased with 2010 as point of reference, 2010 (N = 1548–1562), 2011 (N = 1038–1050) and 2015 (N = 1000–1009)

for problem design are important, as problems do not always just magically appear in a format that calls for specific engineering solutions.

The risk of overemphasising problem solving and neglecting problem design is that engineers might adopt a reactive role, as noted by Downey (2005, p. 588).

> In sum, rapid technological change appears to make visible a unique vulnerability in engineers' identification with technological development and dominant understanding of themselves as technical problem solvers. By claiming jurisdiction only over the solving of technological problems, engineering has positioned itself as society's technological consultant, there to help but only when asked. (Downey 2005, p. 588)

Another indicator of the re-active role of engineers is that there is limited focus on management and thereby the organisation of the problem solving process. Even though students are just about to enter working life, the items related to vocation and business are ranking relatively low.

Comparing students' perception of preparedness at the beginning of their study, after the first year and in the last phase of study before graduation shows that the top five in terms of increasing student preparedness relates to engineering analysis, engineering tools, data analysis, science, and conducting experiments, see Fig. 22.5. Only in one case, regarding leadership, the sense of preparedness has not increased at all throughout the study.

Figure 22.5 shows the emphasis on the domain specific engineering skills throughout engineering education and thereby portrays engineering education as a place where generalists turn into specialists, who within their specific domain are well prepared in terms of process-competencies, yet less prepared when it comes to relating these skills to business or the broader context. In conclusion, there is still a way to go in order to broaden the conceptualisation of employability in higher education.

22.4.4 Developing Employability Skills

If these data are to be used as a basis for recommendations to develop engineering skills, it is important to consider that not only the engineering institutions, but also the students have a responsibility to take seriously the learning opportunities offered to them. To shed light on the impact of students' motivation, we have based our study on the assumption that students who consider a skills area to be very important or decisive for engineering work, are motivated to learn. Thereby we assume that the lack of preparedness can, to a higher extent, be traced back to educational system failure. Figure 22.6 shows the percentage of students that do not, or only to a minor degree, feel prepared in areas that they consider as decisive or of high importance.

As seen in Fig. 22.6 especially communication, sustainability and business areas are indicated as areas that students find of high importance and yet they are moving on from their institutions to employment with a sense of being unprepared.

When students were asked to indicate teaching and learning activities that at the end of their education they find important for their future work, 2 out of 3 students pointed specifically to the master project as being of high importance (N = 890–897). In general, students indicated that the projects became more relevant for their future employment during the study. This indicates a move from more discipline oriented projects, made to socialise students to the methods within the discipline, to more real life projects aligned with professional practices at the end of study.

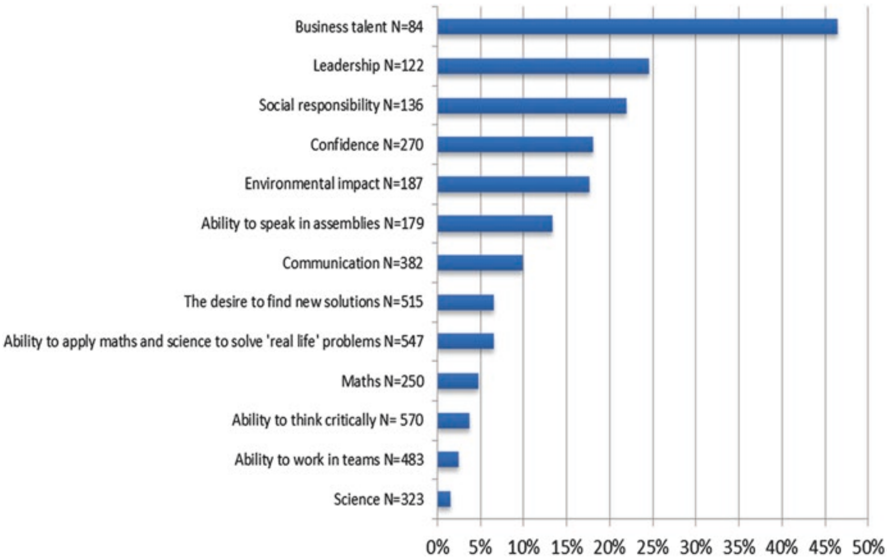

Fig. 22.6 The degree to which students who have rated the particular item as decisive or very important for engineering work at the same time consider themselves to be not at all prepared or prepared to a minor degree (N = 84–570)

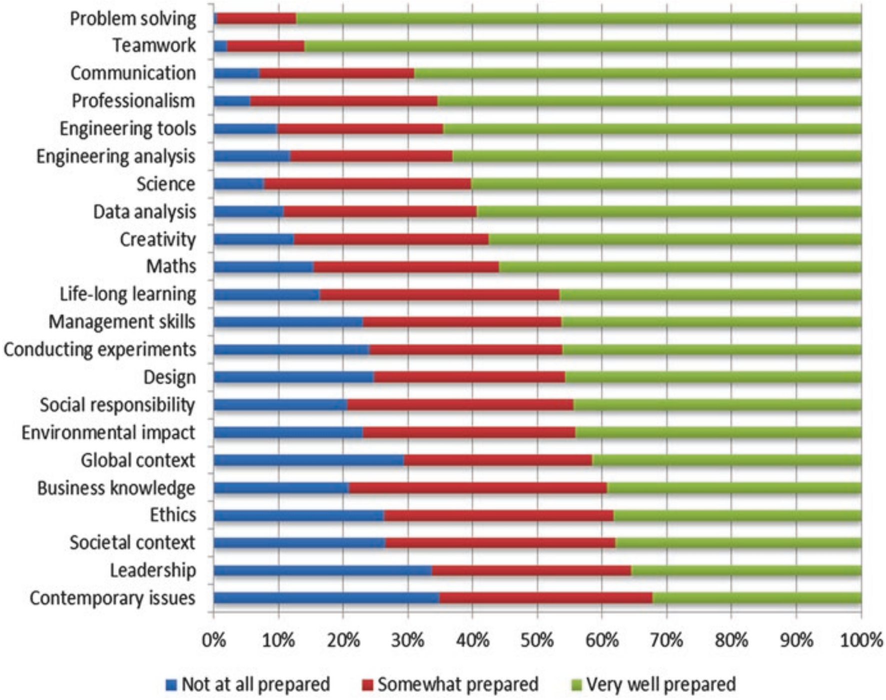

Fig. 22.7 The degree to which students who have stayed in a company for more than 1 month in their study feel prepared (N = 382–389)

Courses are also valued, as about half of the students consider these of high importance. However, at the Master's level, the projects become more important than the course-work. In relation to this, it can be noted that more than half of the students have collaborated with business partners in relation to their project work.

As also pointed out by Elinor Edvardsson Stiwne and Tomas Jungert (2010), so-called company projects seem like an important way to integrate employability into the education. Tymon (2011) further found that internship was the most efficient way to learn about employability. From this perspective, we have chosen to study how students who have been on internship differ in preparedness compared to average.

If we only consider the preparedness of students who have had an internship in a company lasting more than 1 month (see Fig. 22.7) and compare to the average level of preparedness we find:

- Only up to 5% deviation in relation to problem solving, teamwork, engineering tools, professionalism, engineering analysis, math, creativity, life-long learning, social responsibility, ethics and contemporary issues.
- 5–10% deviation in relation to data-analysis, science and the conducting of experiments, where students who had been on internship in companies scored less for very well prepared.

- 5–10% deviation in relation to design, global context, business knowledge, societal context, where students who had been on internship in companies were more prepared and/or included less students in the category “not prepared”.
- 5–10% deviation in relation to environmental impact as fewer students who had been on internship have marked that they do not feel prepared at all.
- 5–10% deviation in relation to leadership, whereas more of the students who had been on internship in companies felt very well prepared – but at the same time, more students also felt not prepared.
- More than 10% deviation in relation to communication, as considerably more students who had been on internship felt more prepared.

These findings show that students who have been in company internships feel more prepared in relation to more generic competencies such as communication and design, business awareness, as well as the societal context and environmental impacts, and less prepared in relation to science, data-analysis and the conducting of experiments. Thereby experiences from companies seem to result in a move to a more process-oriented and contextual employability perspective. Yet the contextual factors related to sustainability are still rather low.

Interestingly enough, more students than average feel very well prepared, and at the same time, more students feel not at all prepared to take on leadership. It can thereby be questioned whether the experiences of leadership in a business context actually make some students more aware that they lack competences in this field.

In relation to internships, it is worth discussing the context in which students are placed and take into consideration whether the institution is related to the private or public sphere. This study has not covered this aspect, but studies are needed to investigate how students consider employability when they have graduated and are in work.

Andrew Jamison et al. (2014) have argued for a transformation of engineering education, which includes academic mode 1 knowledge and market-driven mode 2 knowledge with a community orientation in an integrative mode 3 (see Fig. 22.8). As indicated in Fig. 22.8, this kind of hybrid learning calls for a change in the educational content that is aligned with a broader and more comprehensive understanding of employability and for partnerships moving beyond academia and private partners.

22.5 Concluding Remarks and Recommendations

Employability is and should be a contextual and ever changing concept. Higher education institutions are partners in this co-construction of meaning, not only by interpreting the needs of society today, but also by anticipating the needs of the society of tomorrow. In this paper, we have proposed a comprehensive definition of employability that combines scientific and domain specific engineering skills with process competencies (being transferable and generic in nature) and a concern to the business and societal context in which engineering work is embedded.

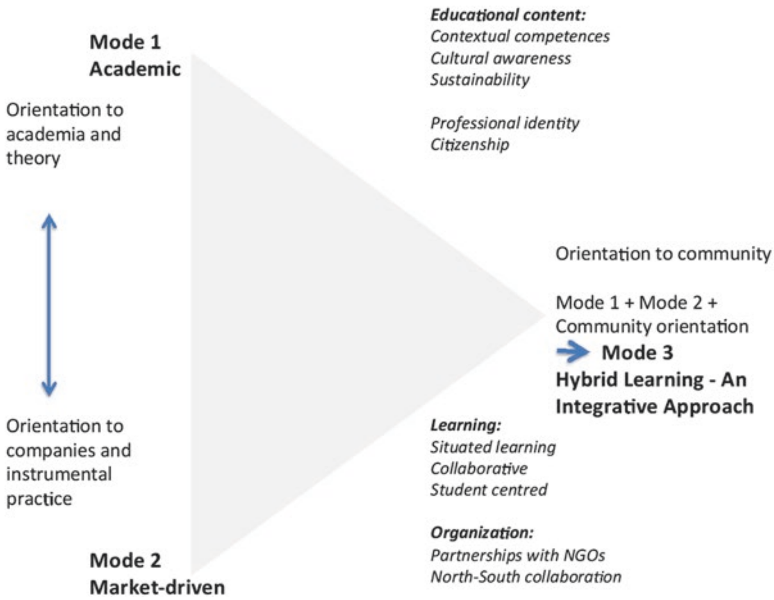

Fig. 22.8 Hybrid learning as a combination of mode 1 and 2 knowledge combined with a community orientation and new perspectives of this Mode 3 on the educational content, learning principles and key partners in the organisation of programmes. (Jamison et al. 2014)

The student perspective revealed in the Danish study on employability shows that Danish engineering students develop increasing attention to life skills during their study – including the ability to think critically and to communicate. However, if we look at what engineering students find most important in regard to employability, we also see an increasing focus on the more discipline related engineering skills such as engineering analysis, engineering tools and data analysis throughout the study. There is a kind of instrumental turn in what students think matters in engineering work throughout their study, and a general lack of attention to more contextual factors, including business awareness, leadership as well as the broader societal perspectives such as environmental and social responsibility. However, students who have been on internships for more than 1 month feel more prepared in relation to more generic competencies such as communication and design as well as the contextual factors, although the attention towards contextual factors is rather low.

This study outlines Danish engineering students' views on employability and how prepared they feel to enter into future working life. But why not create awareness among staff and students of the different conceptualisations of employability skills – why not reflect on and question the implicit understanding of employability, which is embedded in educational institutions? Why not visualise the change in students' perception of what matters, and get different stakeholders to reflect on the paths we have laid down for students to follow?

The study shows a strong focus on problem solving, but little attention to contextual factors. If problem solving is carried out without more comprehensive considerations as to why the problem evolved, and as to who has a stake in the problem and the culture in which new solutions are to be appropriated, we might make solutions that solve one problem and create others. In real life, the impact will show and might backfire whereas in an isolated study the context of the impacts might never show. This part of real life engineering seems only to get minor attention.

Proactive pedagogical models that will mirror the learning processes in a work place situation are needed – defining problems from a system perspective, working on projects, creating new products through participatory design and decision-making processes, inter-disciplinary and intercultural communication, leadership, etc. In this way, proactive pedagogical models can provide students with generic process competences. Problem-based learning (PBL) or the "conceive, design, innovate and operate" (CDIO) perspective are foundations of models, which to a great extent try to provide such a mirror or simulation of real life engineering practice.

However, pedagogical models focused on the how and not on the what, why and who, will not ensure that engineers will design sustainably sound products for our future society. To achieve this, teaching about what, which could be called contextual knowledge, education for sustainable development (ESD), science, technology and society (STS) or whatever approach is taken to contextualise, has to be embedded in the educational model. Internships and business projects are ways forward, however, as employability is contextual in nature, student interaction with different types of stakeholders is needed – private and public organisations as well as communities at large.

If this is not what we are aiming for – what are we then talking about? Are we talking about employability for deskwork – engineers in front of the computer making calculations and analysis for others to make judgements? Are we talking about employability as a reflection of yesterday's workplace in the private sector? Are we talking about engineers who will react to specific demands from clients, but will not be able to act proactively to propose new creative and sustainable solutions? If we want to move beyond this discourse, a more comprehensive view on employability is needed.

References

ABET. (1995). *A vision for change: A summary of the ABET/NSF industry workshops*. Retrieved from: http://bioinfo.uib.es/~joe/semdoc/PlansEstudis/ABET_Criteria_PTE/Vision.pdf

ABET. (2006, 17 Jan 2007). *Engineering accreditation criteria 2006–7*. Retrieved from http://www.abet.org/LinkedDocuments-UPDATE/CriteriaandPP/E00106-07EACCriteria5-25-06-06.pdf

ABET. (2011). *Criteria for accrediting engineering programs*. Retrieved from http://abet.org/eac-current-criteria/

ABET. (2014). *Criteria for accrediting engineering programs*. Retrieved from http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf

Akkerman, S. F., & Bakker, A. (2011). Crossing boundaries between school and work during apprenticeships. *Vocations and Learning, 5*, 153–173. https://doi.org/10.1007/s12186-011-9073-6.
Assiter, A. (1995). *Transferable skills in higher education. Teaching and learning in higher education series*. New York: ERIC.
Atman, C., Sheppard, S., Turns, J., Adams, R., Fleming, L., Stevens, R., … Lund, D. (2010). *Enabling engineering student success*. Retrieved from http://www.engr.washington.edu/caee/CAEEfinalreport20101102.pdf
Bennett, R. (2002). Employers' demands for personal transferable skills in graduates: A content analysis of 1000 job advertisements and an associated empirical study. *Journal of Vocational Education & Training, 54*(4), 457–476. https://doi.org/10.1080/13636820200200209.
Bourgeois, E. (2002). *Higher education and research for the ERA: Current trends and challenges for the near future* (Final Report of the STRATA-ETAN expert group. Foresight for the development of higher education/research relations). Bruxelles: Commission européenne, DG Recherche.
Branine, M. (2008). Graduate recruitment and selection in the UK: A study of the recent changes in methods and expectations. *Career Development International, 13*(6), 497–513.
BusinessDictionary. (2016). *Employability skills*. Retrieved from http://www.businessdictionary.com/definition/employability-skills.html
Dahlgren, M. A., Hult, H., Dahlgren, L. O., af Segerstad, H. H., & Johansson, K. (2006). From senior student to novice worker: Learning trajectories in political science, psychology and mechanical engineering. *Studies in Higher Education, 31*(5), 569–586. https://doi.org/10.1080/03075070600923400.
Downey, G. (2005). Are engineers losing control of technology?: From 'problem solving' to 'problem definition and solution' in engineering education. *Chemical Engineering Research and Design, 83*(6), 583–595.
Dunne, E., Bennet, N., & Carre, C. (2000). Skill development in higher education and employment. In *Differing visions of a learning society. Research findings* (Vol. 1, pp. 105–137). Bristol: Policy Press.
Engineering Council UK. (2004). *EUR-ACE standards and procedures for the accreditation of engineering programmes*. First Draft 1204. Retrieved from http://www.engc.org.uk/documents/EURACE_First_Framework_1204.pdf
Engineers Australia. (2006). *Accreditation criteria and guidelines*. Retrieved from Canberra: http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=0B19D0FF-0BC5-BAC1-DB36-6FB8599DDE67&siteName=ieaust
EU Commission. (2008). *Improving competences for the 21st century: An Agenda for European Cooperation on Schools*. Brussels: Commission of the European Communities Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52008DC0425.
Fallows, S. J., & Steven, C. (2000). *Integrating key skills in higher education: Employability, transferable skills, and learning for life*. New York: Psychology Press.
Holgaard, J. E., Petersen, L. S., Guerra, A., & Kolmos, A. (2016). Getting a hold on the problem in a problem-based learning environment. *International Journal of Engineering Education, 33*(3), 1070–1085.
Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education, 103*(2), 253–273.
Kearns, P. (2001). *Generic skills for the new economy. Review of research*. New York: ERIC.
Knight, P., & Yorke, M. (2003). *Assessment, learning and employability*. Maidenhead: McGraw-Hill Education.
Knight, P., & Yorke, M. (2004). *Learning, curriculum and employability in higher education*. Psychology Press.
Kolmos, A., & Bylov, S. M. (2016). *Ingeniørstuderendes forventning og parathed til det kommende arbejdsliv: Arbejdsrapport no. 1* (8791404800). Retrieved from http://www.ucpbl.net/digitalAssets/154/154582_proceed2work_arbejdsraport1.pdf

Kolmos, A., & Holgaard, J. E. (2010). Responses to problem based and project organised learning from industry. *International Journal of Engineering Education, 26*(3), 573–583.

Kolmos, A., Holgaard, J. E., Bylov, S. (2016). *The transition from engineering education to work*. In Proceedings SEFI Annual Conference, 2016, Tampera, Finland.

Konkola, R., Tuomi-Gröhn, T., Lambert, P., & Ludvigsen, S. (2007). Promoting learning and transfer between school and workplace. *Journal of Education and Work, 20*(3), 211–228. https://doi.org/10.1080/13639080701464483.

Lamb, F., Arlett, C., Dales, R., Ditchfield, B., Parkin, B., Freng, W. W. (2010). *Engineering graduates for industry*. Retrieved from http://www.raeng.org.uk/publications/reports/engineering-graduates-for-industry-report

Magnell, M., Geschwind, L. A., Gumaelius, L. B., Kolmos, A. (2014). *Faculty approaches to working life issues in engineering curricula.* Paper presented at the 121st ASEE Annual Conference & Exposition.

Markes, I. (2006). A review of literature on employability skill needs in engineering. *European Journal of Engineering Education, 31*(6), 637–650. https://doi.org/10.1080/03043790600911704.

Moreau, M. P., & Leathwood, C. (2006). Graduates' employment and the discourse of employability: A critical analysis. *Journal of Education and Work, 19*(4), 305–324.

Mourshed, M., Farell, D., Barton, D. (2012). *Education to employment: Designing a system that works*. Retrieved from http://www.compromisorse.com/upload/estudios/000/222/Education-to-Employment_FINAL.pdf

National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Retrieved from http://books.nap.edu/catalog/10999.html

National Society of Professional Engineers, N. (2016). NSPE code of ethics for engineers. *Journal of The Minerals, Metals & Materials Society, 45*(4), 14–16.

Nilsson, S. (2010). Enhancing individual employability: The perspective of engineering graduates. *Education+ Training, 52*(6/7), 540–551.

Rosenberg, S., Heimler, R., & Morote, E.-S. (2012). Basic employability skills: A triangular design approach. *Education+ Training, 54*(1), 7–20.

Saeki, H., & Blom, A. (2011). *Employability and skill set of newly graduated engineers in India* (WPS5640). Retrieved from http://siteresources.worldbank.org/DEC/Resources/84797-1154354760266/2807421-1288872844438/7530108-1307466729777/Employability_and_Skills.pdf

Spinks, N., Silburn, N., & Birchall, D. (2006). *Educating engineers in the 21st century: The industry view*. Retrieved from http://www.raeng.org.uk/news/releases/henley/pdf/henley_report.pdf

Stiwne, E. E., & Jungert, T. (2010). Engineering students' experiences of transition from study to work. *Journal of Education and Work, 23*(5), 417–437. https://doi.org/10.1080/13639080.2010.515967.

Taylor, A. (2005). What employers look for: The skills debate and the fit with youth perceptions. *Journal of Education and Work, 18*(2), 201–218. https://doi.org/10.1080/13639080500085984.

Tomlinson, M. (2008). 'The degree is not enough': Students' perceptions of the role of higher education credentials for graduate work and employability. *British Journal of Sociology of Education, 29*(1), 49–61.

Tymon, A. (2011). The student perspective on employability. *Studies in Higher Education, 38*, 841–856. https://doi.org/10.1080/03075079.2011.604408.

Williams, C. (2005). The discursive construction of the 'competent' learner-worker: From key competencies to 'employability skills'. *Studies in Continuing Education, 27*(1), 33–49. https://doi.org/10.1080/01580370500056422.

Yorke, M. (2004). Employability in the undergraduate curriculum: Some student perspectives. *European Journal of Education, 39*(4), 409–427.

Anette Kolmos Professor in Engineering Education and PBL, Chairholder for UNESCO in Problem Based Learning in Engineering Education, and Head of The Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, Aalborg University, Denmark. Guest professor at KTH Royal Institute of Technology and Guest Professor at UTM University Technology Malaysia 2011–2013. President of SEFI 2009–2011 (European Society for Engineering Education). Founding Chair of the SEFI-working group on Engineering Education Research. During the last 20 years, Dr. Kolmos has researched the following areas, primarily within Engineering Education: development and evaluation of project based and problem based curriculum, change from traditional to project organized and problem based curriculum, development of transferable skills in PBL and project work, and methods for staff development. She has published more than 200 publications in these areas. She is Associate Editor for the *European Journal of Engineering Education* and was Associated Editor for *Journal of Engineering Education* (ASEE). Member of several organizations and committees within EER, national government bodies, and committees in the EU.

Jette Egelund Holgaard Associate Professor within the field of Sustainability, Technology and Organizational learning at the Department of Planning, Aalborg University. She has a M.Sc. in Environmental Planning and a Ph.D. in Environmental Communication. Both degrees are from Aalborg University. Her primary research interest is how Problem Based Learning models and methodologies can frame and enhance engineering education for sustainability. She has published more than 90 publications in relation to this area of research. She is affiliated to the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO.

Chapter 23
Conclusions

Steen Hyldgaard Christensen, Bernard Delahousse, Christelle Didier, Martin Meganck, and Mike Murphy

Using both an engineering education and engineering practice lens our aim with this volume has been to examine:

1. The tension between engineering and business related to the development of capitalism from the mid-nineteenth century to the early twenty-first century. Chapters 2, 4, 7, and 8
2. The tension between academia and industry historically and presently. Chapters 10, 21, and 22
3. Dynamics in university restructuring and the concomitant role of STEM fields in third mission activities. Chapters 11 and 12
4. Configurations of the engineering-business nexus with regard to aims and purpose of specific engineering degree programs and business management programs. Chapters 17, 18, and 20

S. H. Christensen (✉)
Department of Development & Planning, Aalborg University, Aalborg, Denmark
e-mail: steenhc@plan.aau.dk

B. Delahousse
Département Mesures Physiques, Université de Lille – IUT « A » de Lille, Villeneuve d'Ascq Cedex, France

C. Didier
Département des sciences de l'éducation UFR DECCID, Université de Lille, Villeneuve-d'Ascq, France
e-mail: christelle.didier@univ-lille.fr

M. Meganck
Faculty of Engineering Technology, Technologiecampus Gent, KU Leuven, Gent, Belgium
e-mail: martin.meganck@kuleuven.be

M. Murphy
Academic Affairs, Digital & Learning Transformation, Dublin Institute of Technology, Dublin 2, Ireland
e-mail: mike.murphy@dit.ie

© Springer Nature Switzerland AG 2019

S. H. Christensen et al. (eds.), *The Engineering-Business Nexus*,
Philosophy of Engineering and Technology 32,
https://doi.org/10.1007/978-3-319-99636-3_23

5. Professional/occupational value systems in engineering and business cultures respectively, and how they are exhibited in examples of their interaction. Chapters 2, 3, 4, 5, 6, 16, and 19
6. Ways in which engineers create value and protect value for their firms. Chapters 13 and 14
7. Movements to reshape, reform, or reject the engineering-business nexus. Chapters 7, 9, 10, 13, and 15
8. Shortcomings of the current economic growth paradigm associated with deregulated capitalism. Preface, Chap. 3, General Introduction, Conclusions.

At the beginning of the General Introduction the business corporation and its pathological pursuit of profit and power was contemplated. Here a few opening remarks on capitalism should be made before we proceed to the conclusions that can be taken away from this volume.

Capitalism in its current globalized and deregulated form is a main feature of the economic system in which engineering-business relationships are embedded. According to the analysis of capitalism undertaken by French sociologists Luc Boltanski and Eve Chiapello in their 1999 book *The New Spirit of Capitalism* (English version 2007) deregulated capitalism is compelled – if it is to succeed in continuously being able to attract engineers to assume work functions either as salaried professionals or as managers in the business corporation, firm, or other capitalist organization – to inculcate an animating spirit that can provide attractive, exciting life prospects, while supplying guaranties of security and moral reasons for people to do what they do. In keeping with this perspective, to be effective the new spirit of capitalism must impart a certainty to engineers and other *cadres* (managers) about the right things to do to make a profit, and the legitimacy of doing so. Hence according to the authors the spirit of capitalism must meet a demand for self-justification, in particular to resist anti-capitalist critique referring to generally accepted conventions of what is considered just or unjust.

In the student and worker protests during the late 1960s two types of anti-capitalist critique were mobilized, namely the *social critique* of the left and the *artistic critique* associated with all kinds of bohemianism. The first criticizes capitalism for its tendency to create social inequalities and is associated with the social-democratic welfare state project of the 1970s. The *artistic critique* is directed towards capitalism's cultural tendencies to encourage philistinism, boredom, alienation and conformism, and came to be embraced by leading segments of international capital. It was given expression in the new management discourse associated with post-Fordism and neoliberalism. Briefly put, the promise of autonomy, creativity, freedom, and personal fulfilment inherent in the *artistic critique* supplied the core ideological resources of the new animating spirit of capitalism. The key function of this animating spirit is thus to mobilize and motivate strategically crucial segments of the population – the professionals or *cadres* – responsible for managing and directing capital accumulation (Couldry et al. 2010).

Boltanski and Chiapello's analysis of the ways whereby the hegemony of the leading sections of international capital is exercised demonstrates that this does not necessarily require that the majority of a given population embraces the ideological assumptions of the hegemonic groups with any enthusiasm provided that strategically significant sections of the *cadres* can be persuaded to do so. The authors further argue that the new spirit of capitalism should no longer be understood in terms of an ethos in the Weberian sense. Max Weber famously contended in his 1904 classic *The Protestant Ethic and the Spirit of Capitalism* that the protestant ethic made possible and encouraged the development of capitalism in the West. Extending the work of Weber, but in contrast to him, Boltanski and Chiapello see the new spirit of capitalism as a legitimating apparatus supplying resources for *cadres* or future *cadres* peculiar to each age to alleviate the uneasiness triggered by the following three questions (Boltanski and Chiapello 2007, p. 16):

- How is committed engagement in the processes of accumulation a source of enthusiasm, even for those who will not necessarily be the main beneficiaries of the profits that are made?
- To what extent can those involved in the capitalist universe be assured a minimum of security for themselves and their children?
- How can participation in capitalist firms be justified in terms of the common good, and how, confronted with accusations of injustice, can the way it is conducted and managed be defended?

Examining management discourse in the 1960s and the 1990s they have found that the discourse in the 1990s underwent a significant change compared to the former, but also that in both discourses profit alone is not seen as a very inspiring goal to mobilize and motivate managers. *Cadres,* they say, "initially, in the 1960s, and then the workforce as a whole in the 1990s wanted "genuine reasons" for engaged commitment" (ibid., p. 63).

A closer inspection of John Mackey and Raj Sisodia's 2014 book *Conscious Capitalism: Liberating the Heroic Spirit of Business* shows that, if Boltanski and Chiapello had endeavored to follow up on their 1999 study and extended their analysis of management discourse well into the second decade of the twenty-first century, there would be good reasons to believe that their reasoning would still be valid. Now the "genuine reasons" endorsed by authors like Mackey and Sisioda are (1) higher purpose, (2) stakeholder integration, (3) conscious leadership, and (4) conscious culture and management. According to Mackey and Sisodia there is nothing inherently wrong with business and capitalism.

A number of authors included in this volume either explicitly or implicitly refer to various kinds of legitimating frameworks such as *Conscious Capitalism, Corporate Social Responsibility, Marxism, Engineering Ethics, De-growth* and more. All of these solution frameworks may be seen as reflecting the fact that engineers have increasingly been called upon to articulate the "public good" that they are mandated to build, reinforce, and protect. However, at the analytical level this might entail a critical engagement with the deep structures of capitalism.

Therefore relevant in this context is also the analysis of deregulated capitalism put forward by Naomi Klein in her 2014 book *This Changes Everything: Capitalism* *vs. the Climate.* Here Klein highlights the roadblocks for dealing effectively with climate change:

> The three policy pillars of this new era are familiar to us all: privatization of the public sphere, deregulation of the corporate sector, and lower corporate taxation, paid for with cuts in public spending. Much has been written about the real-world costs of these policies – the instability of financial markets, the excesses of the super-rich, and the desperation of the increasingly disposable poor, as well as the failing state of public infrastructure and services. Very little, however, has been written about how market fundamentalism has, from the very first moments, systematically sabotaged our collective response to climate change, a threat that came knocking just as this ideology was reaching its zenith. (Klein 2014, p. 19)

According to Klein it seems to have been our collective misfortune that the diagnosis of climate change by the scientific community was made at the precise moment in the late 1980s when what came to be called "globalization" began. This was also the moment when the reigning elite minority in the U.S. was enjoying more unfettered political, cultural and intellectual power and leverage than at any point since the 1920s when Veblen published *Absentee Ownership and Business Enterprise in Recent Times: The Case of America*.

If Boltanski and Chiapello's book convincingly highlights the animating spirit of capitalism and Klein's book the roadblocks of deregulated capitalism to deal effectively with climate change, Thomas Piketty in turn in his 2014 book *Capital in the Twenty-First Century* highlights the evolution of capitalism from the eighteenth century to the present and shows how the main driver of inequality – the tendency of returns on capital to exceed the rate of economic growth – threatens to create inequalities of grand proportions able to arouse discontent and undermine democratic institutions, values and ideals. It seems obvious that deregulated capitalism in many ways has become dysfunctional and that if capitalism has to be saved from itself it must be changed.

In scaffolding this volume the first part of the *General Introduction* has served to present and contextualize key overlapping questions that have informed the volume, and at the beginning of the *Conclusions* our aims of using an engineering education and practice lens were specified thereby indicating that a number of subjects that were to be examined cut across the four parts of the volume. However, the following conclusions will be organized somewhat differently as we seek to identify themes and subthemes across the chapters in each part that have emerged during the process and related to which plausible claims are made. These themes and subthemes may not be appropriately captured alone by the title of the respective part.

23.1 Conclusions: Chapters in Part I

Discussions on parallelisms, contradictions and interferences between engineering and business ideologies and practices implicitly or explicitly refer to conceptions of value systems which are supposed to be present in the respective occupational fields. Michael Davis, in Chap. 2, defends an almost Weberian ideal type of professionalism: professionals are supposed to stick to "higher aims" that transcend both the individual and the organization-bound interests in which people work. Any practice has its own internal ideals and values; ethics however needs some form of alterity, in the form of an external input of criteria (often related to some notion of the public interest). Professionals are there to guarantee that these external criteria are respected. For doing so, their capacities and independence must be respected, and professionals must claim that independence – if need be against the interests and immediate expectations of their employers, colleagues or other stakeholders. Although theoretically backed up by a professional corps to which they belong, this may require professionals to take an individual, even heroic stance. In line with his earlier writings, Davis claims engineers to be professionals (or at least, they should be considered as such – both by themselves and by others), whereas business management would be limited to a mercenary calling, hence lacking the reference to external ideals. He rejects objections that engineers would either not be "real professionals", or that in practice the professional independence of engineers would be impaired by organizational or business constraints. The very core of professionalism actually lies in its strong normative stance.

The other chapters in Part I can be read as comments, contextualizations, and criticisms of this ideal type of professionalism (be it the idea of professionalism in general, of its application to business or engineering). In Chap. 6, Christelle Didier invites us to reframe the concept of professionalism itself: not as an obvious ideal with a universal calling, nor as an ideologically loaded imperialistic power structure, but referring to the contingencies of how societal practices evolve throughout history – in her case illustrated by a thorough study of the evolution of occupational and societal groups mainly in France (but also in other European countries), from medieval times till today. She links the main evolutions and events with political, economic, socio-cultural, philosophical and even theological insights. The variety of roles, structures and meanings surrounding occupational practices leads her to the observation that the concept of professionalism indeed serves as a reference for the organization and ethics of e.g. engineering in some countries, but is rather meaningless or void, or at least functions differently in other regions. This leaves room for ethics to be perceived otherwise – both for engineering and for business: a vision that is more in touch with the actual roles and capabilities of engineers and managers.

Eddie Conlon (Chap. 3) and Luc Bégin (Chap. 4) both consider reducing engineering ethics to the mere sticking to rules of professionalism to be unrealistic: it fails to appreciate the structural mechanisms of capitalism (Conlon), or at least misses the complexities of the situations in which engineers work (according to the empirical observations of Bégin and his colleagues). Conlon moots the idea of "captivity of the corporate engineer" – an idea that is explicitly and strongly discarded by Davis in Chap. 2. Relying on analytical frameworks in social sciences and politology ("Critical Realism", and Marxism), Conlon considers the factual boundaries and limits of the capitalist mode of production to be part of reality: actual events in economy and society, and the lived experience of workers can often be explained (or at least interpreted) with the generative mechanisms of capitalism as a framework.

At first sight, the institutionalized situation of employment is applicable to engineers too; they too are part of the dynamics of the labor-capital relationship. Yet, engineers are often seen by other workers as representatives of management (as they have to take care of the actual implementation of corporate policies), and career evolution often drives them towards more management-oriented functions. This makes the relationship between engineers and business even more intricate and complex than it already is for other workers. Companies have to function within the general dynamics of capitalism, and workers are confronted with a multitude of intra-organizational aspects in their employment context (decision-making processes, training, control and feedback procedures, etc.): a complexity that is ignored if one sticks to the image of the isolated professional. Conlon illustrates this further by commenting on the way engineers play a role in safety issues and in climate dilemmas.

Luc Bégin and his colleagues carried out surveys and interviews with hundreds of engineers in Québec, in the aftermath of some scandals in which engineers were involved and served as ethics consultants for the Ordre des Ingénieurs du Québec. In Chap. 4 they present some obstacles that engineers report, referring to the actualization of the "professional ideal". In Québec, engineering is organized as an official "profession": membership of the Order is compulsory, and one of the functions of the order consists in watching over deontological behavior. Yet, many engineers experience "multiple loyalties", where the professional ideals may be at odds with formal or informal engagements engineers have viz. their employer, their colleagues, etc. In the surveys and interviews, many engineers report having been witnesses of improper behavior in their immediate professional environment, but only a small minority reports such behaviors to the professional organization – even though the Code of conduct of the organization requires them to. In an attempt to further explore and understand this phenomenon, Bégin describes a process of de-professionalization: not that engineers would consciously deviate from the values and ideals of the professional organization, but that they no longer experience their activity to relate to that ideal. A "weakening of the professional identity" is at hand. Further attempts to fathom the causes and the extent of this de-professionalization indicate that the professional status seems to be nibbled on from various sides: some engineers report that they have too little flexibility in exercising their professional judgment; others refer to the factual shift of their tasks towards strategic decision-making.

Chapter 5 cross-references the American ABET and the European EUR-ACE-standards for engineering education programs with a set of "prima facie duties" (like elaborated by W.D. Ross) and with elements from Aristotelian virtue ethics. The author, Glen Miller, believes these approaches to be more practical for engineering ethics than the traditional ethical models like utilitarianism or Kantian deontological ethics. The final movement of Miller's chapter consists in commenting on the trajectory many engineers follow during their career: though starting in a function where their scientific and technical skills form the core of their work, the succession of promotions leads many engineers towards first coaching-oriented functions, and later on towards strategical orientation. For some organizations however, dual promotion ladders could be recommended: it would allow to reward engineers for their proper engineering work, without interference by management-laden tasks.

It is reported that Robert Lund, in the meeting that led to the decision to launch the Challenger space shuttle despite the warnings expressed by expert engineers, was asked to "*put off his engineering hat and put on a manager's hat*". Between engineers seeing themselves as "mere employees" on the one side, and engineers becoming managers on the other side, it is not even always clear what this "engineering hat" would be. References to ideals of professionalism are there to remember the importance of the proper capabilities of engineers. The chapters in Part I of this book confront this ideal with experiences and analyses of engineering work in the context of corporate firms, and highlight some of the resulting tensions. In Chap. 21 of this book, Alan Cheville and John Heywood use the idea of "tensions" instead of "problems" to describe engineering work. Tensions are multifaceted, and require a sense of negotiation that may differ from the straightforward problem solving approach that is often ascribed to engineers. Ignoring the engineering-business tensions or annealing them may seem attractive at first, but may in the end be unproductive. Parts II through IV of this book further explore this field.

23.2 Conclusions: Chapters in Part II

The six chapters in Part II of this volume dwell upon historical reflections on engineering and business ideologies as well as on reforms in higher education that have been influenced by the dominant discourse of neoliberalism associated with the concept of "new public management". Three main themes developed across these chapters are highlighted here: (1) the changing role of the engineer linked to the development of capitalism since the mid-nineteenth century, (2) the concept of employability/employment as a source of tensions or engagement between industry and higher education, and (3) the issue of the commodification of higher education. Incidentally a further feature runs across the six chapters, i.e. "diversity" which relates to the different functions, competences, educational backgrounds and work environments of the modern engineer, thereby emphasizing the high complexity of the engineering-business relationship.

Although the theme of the changing role of the engineer pervades each of the six chapters, it is essentially treated in Chaps. 7, 8 and 9. As observed by Steen Hyldgaard Christensen and Bernard Delahousse (Chap. 7) throughout Thorstein Veblen's work, engineers and technicians at the turn of the twentieth century were depicted as a homogeneous group of well-trained and competent experts who were not driven by a commercial interest but were indispensable both to the conduct of industry and, above all, to the welfare of their human fellows. However, due to the development of mass production and technological advance, together with the subsequent growing specialization of industry, Veblen pointed out to the increasing dichotomy between the captains of industry who became increasingly self-interested financiers and the industrial experts whose ethos remained to contribute to the public good. In the authors' view, even though Veblen's provocative call for a "Soviet of technicians" did not stand the test, his analysis of the contradictions of capitalism in terms of a contradiction between industry and business has brought key insights regarding the current practices of corporation finance.

Chapter 8 and 9, respectively by Janis Langins and by Wang Nan and Li Bocong, also emphasize the preeminent social role of the engineer for the community and the increasing importance of business over engineering. Langins uses Kipling's biblical allegory of two sisters, Martha and Mary, to portray engineers as professionals making the world function and serving the community. At the same time, the author stresses the fact that, since the lifetimes of Veblen and Kipling, the occupation of the engineer has become increasingly complex as it currently encompasses not only the technician's "dirty" and somewhat dangerous tasks but also the nobler, and less risky, functions of the designer, planner or manager. As new functions, such as communication and industrial organization, began to be part of the engineer's profile, the boundaries between engineering and business became increasingly blurred. Conversely, according to Langins, the values of the engineer, namely efficiency and rationality, have permeated modern corporations, thereby turning the conflict between engineering and business ideologies into a tense nexus.

In a different context, i.e. the transformation from a planned economic system to a market system during the Long 80s, Wang Nan and Li Bocong note that the engineering community comprising both engineers and entrepreneurs underwent huge changes. They recall that in the Chinese tradition the "producers" (whether manual, technical or intellectual) were considered as the honourable classes whereas the merchants and artisans had a lower social status. After the restriction of engineers and the disappearance of entrepreneurs under Mao Zedong in the 1950s, when the managerial system was highly centralized and planned, the Long 80s saw the rebirth of private enterprises engaged in risk-taking and competitive ventures. In this new context the engineer was regarded as the technical authority working on the design of projects and their feasibility but also as the technical manager responsible for the organizational, administrative and social tasks, thus reflecting a close engineering-business relationship. The combination of these functions culminated in the socially oriented phenomenon of the Sunday engineers, whereby engineers working in urban enterprises during the week were invited to help the populations living in townships and small villages to get a better life.

The second theme bears upon the concept of employability/employment as a source of tensions or engagement between industry and university education in terms of the missions of the latter. John Heywood (Chap. 10) and Mike Murphy and Michael Dyrenfurth (Chap. 11) support a common view that to prepare graduates that are immediately employable in industry is impossible without shared responsibility between industry and academia. While Heywood focuses on the issue of the employability of engineering graduates from the perspective of competences and skills to be acquired, Murphy and Dyrenfurth examine the central question of job creation as part of the university's third mission "engagement" activities. For Heywood, the core competence "acting as an engineer in an organization" cannot be learnt only through university courses, as it encompasses a diversity of non-technical skills, such as socialization processes and managerial competencies that can be developed only within a company. It is a developmental process which requires interaction between periods of academic study and industrial work in order to help students acquire professional competence. Heywood notes that employers believed that industrial training e.g. via the sandwich course system could make graduates more immediately useful. This system once regarded as an ideal curriculum for higher engineering education relied on the actual cooperation between academia and industry not only for providing placements to students, but also for taking part in the graduation process. But it did not have all the success it deserved for lack of operational co-responsibility. The author concludes that if engineering education is to progress, policy-makers in both sectors need to understand the extensive knowledge base that has been built on previous experiences, so as to learn to share responsibility, for the benefit of future engineers.

Chapter 11 by Murphy and Dyrenfurth also tackles the issue of employability but from the perspective of sustainable job creation and economic growth which constitute the third mission, or "engagement", activities of the entrepreneurial university. They advance that the university has expanded, and still expands, from traditional first and second mission activities, respectively teaching and research, to embrace more responsibilities contributing to the imperative of job creation and sustainability combined with economic development. The authors argue that the best mechanism to create and maintain jobs is to attract large companies into a given region or country and that universities, as centres of knowledge, can provide support not only through targeted research but also through the high-quality education and adaptability of the regional workforce. The same argument applies to the support in favour of small and medium-sized companies and to start-ups, as they are large job providers. The authors then point to the fact that higher education is of high value both to the individual graduates in terms of job and career prospects and to industry in terms of hiring a well-prepared workforce to support the company's goals. In this respect, higher education can still be viewed as a very good investment.

Investment is also part of the third thematic, i.e. the commodification of higher education, developed mostly by Murphy and Dyrenfurth (Chap. 11) and by Steen Hyldgaard Christensen (Chap. 12). The first two authors, after examining the central contribution of universities to graduates' employment and to economic growth, explore how research universities are becoming increasingly entrepreneurial by taking on new roles, while Christensen interrogates two dominant institutional logics of higher education, namely those of the university as a social institution and the university as a profit-seeking corporation. For Murphy and Dyrenfurth the entrepreneurial university generates a win-win situation since companies benefit from the results of research while university researchers benefit from the ideas and requirements of business. They also argue that governments should implement a more interventionist policy as regards the industry-higher education relationship: not only should they invest more in universities, but they should also create a positive business environment, e.g. through fiscal advantages, in order to attract investment whether at home or from abroad, thus reinforcing their competitiveness.

Acknowledging the major difficulty that the shareholders' interests are not aligned with labor's job creation and sustainability, the two authors conclude that the most dynamic and innovative universities are those capable of responding to and implementing all three academic missions under the tripartite umbrella of business, government and higher education.

In Chap. 12, Christensen first explores how the reduction of public investment in American higher education has forced universities to look for alternative funding, thereby departing from their status as educational communities to become profit-seeking corporations, in which education is seen as a commodity, and students as both consumers and competitors. The author then analyzes the effects of this corporatization of higher education: vocational drift of curricula, outsourcing of teaching, broken link between teaching and research, downgrading of teachers associated with increasing power of administrators, all of which contribute to make a breach in the social charter between higher education and society by not serving well the student, faculty and society at large. In this respect, after identifying three different social charters that stem from communitarian, neoliberal, and utilitarian philosophies, Christensen evidences that the neoliberal corporate university with its emphasis on economic efficiency and managerialism has radically changed its nature and its ethos. Drawing on examples from the restructuring of US universities, he lists in details the distinctive features of the corporatized university so as to highlight its advantages and drawbacks, thereby giving food for thought to the different educational actors and policy-makers. He concludes by advancing that the neoliberal charter should be renegotiated between university and society in order to realize a blending of the traditional model and the industrial model of education that students and faculty should contribute to.

23.3 Conclusions: Chapters in Part III

The four chapters in Part III each examined in their own way the practice of engineering within a business context, and the interplay between both business and engineering. The core issue developed and described in these chapters is that organizations are essentially social systems in which interactions and interdependencies are governed by different arrangements of complex systems, including technical and social systems. Challenges arise therefore when 'the engineer' interprets the business environment more narrowly as a technical environment.

The scope of the interplay between business and engineering is described by Erik Aslaksen (Chap. 13) as dominated by the need for business to provide opportunities to generate a return on increasing amounts of capital; and also by the fact that engineering automatically generates new technology which presents new business possibilities. He concludes that the dynamic of this relationship between engineering and technology, played out within a business context, is often not appreciated. Consequently engineering, as a profession, has not responded adequately to business environment changes and therefore the practice of engineering is facing a paradigm shift. The key element of this shift is that engineering is becoming a hybrid profession, that in many situations the coupling between human and technological artefacts is so close that it is impossible to make a distinction between the two. Often in today's world engineering work is performed by a *hybrid* (engineer), and that hybrid is not operating very efficiently. Acknowledging this will require a restructuring of the engineering profession and its place in the workforce, but also therefore that the paradigm shift facing engineering cannot be resolved purely from an internal 'engineering-only' perspective.

This is contrasted by James Trevelyan and Bill Williams who set out in Chap. 14 to do just that by examining value creation, and also importantly value protection, as key concepts within the practice of engineering. They observe that because discussions on engineering value creation have focused on technological innovation, many engineers who are not involved in such work fail to appreciate how their work creates or protects value. Importantly, Trevelyan and Williams also conclude, and agree with Aslaksen, that there are existing weaknesses in engineering education, and for Trevelyan and Williams this includes the incorrect view that value creation only occurs through technological innovation. While Aslaksen reaches the conclusion that new types of hybrid engineer are emerging, Trevelyan and Williams seek to expand the more traditional roles of engineering by broadening and extending the definitions and use of *value creation.*

Jane and Bill Grimson (Chap. 15) develop a different but still cogent attack on academic and business practice, in which the salient for this critique comes from the narrowed perspective of the implications of gender inequality. Having set out the arguments against gender inequality, social justice, the waste of human talent, and the strength of diversity, they present a suite of interventions that can be used to successfully tackle gender inequality. They make the case that there is broad agreement on what needs to be done, rather it is the doing that is complex. They begin with the necessity for committed leadership, but also discuss supports for work-life balance, the imperative to develop future women leaders, and importantly the need to tackle unconscious bias. They conclude that failure to take action will have a major impact on the engineering profession's ability to meet the needs of our current and future society. While the crucial element of the argument in Chap. 15 is identifying issues to address gender inequality, the underlying basis can still be looked at as a narrowness of perspective associated with the workplace in which engineers practice their profession.

And indeed Part III concludes nicely with Russell Korte's arguments (Chap. 16) about the challenges that new engineering graduates face as they transition into the workplace. He describes the workplace as a community of practice, or occupational community. It is in the transition phase into this occupational community that the differences between what the engineering student learned and what they now confront are most evident. Korte uses a qualitative, inductive case study method to present clear evidence of the challenges that new graduates face. In the quotes presented, it is possible to see the nature of workplace culture into which these new hires are trying to socialize. He concludes that there is not much to business or engineering without the social organization, and leaves us with the concluding remark that the distinctions between business and engineering communities are mainly disconnected abstractions and tend to disappear in the intricacy of organizational work.

The chapters in Part III (Chaps. 13, 14, 15 and 16) all point to the existing and growing challenge to a narrow interpretation of the engineering profession in the twenty-first century. For different but valid reasons – the imperative to generate a return on investment, the mandate and requirement for gender equality, the justification of value creation and value protection, the socialization process for new engineering graduates – the nexus between business and engineering requires a re-evaluation of the education of the engineer and the practice of the engineering profession. These chapters present strong arguments and evidence that educators and accrediting bodies should not take lightly.

23.4 Conclusions: Chapters in Part IV

In the chapters included in Part IV, the main overall conclusion is the need to change engineering education. The consensus view is that the engineers of tomorrow should better match known and understood developments that are already underway. Mike Murphy, Pat O'Donnell and John Jameson see the hyper-specialization of engineering education combined with engineering identity acting as brakes on educational development for a changing society. Supporters of new types of hybrid engineering-business programs, Michael Dyrenfurth and Gary Bertoline emphasize the need to introduce business ethics content in engineering education, such as corporate social responsibility (CSR) and conscious capitalism. Lovasoa Ramboarisata and Corinne Gendron stress the need for a more critical approach by business, which does not encourage critical thinking enough. In most western countries, higher education is facing a more commercial turn, with more pragmatic expectations for science. In this context, Joakim Juhl and Anders Buch illustrate how such pressures have paradoxically created an opportunity for one Danish university to innovate a new type of hybrid model, which was and is able to attract a more diverse body of students. However, this program might be an exception in a context where, according to Alan Cheville and John Heywood, the financialization of the economy has enforced the trend towards the specialization of engineers. Their suggestion for engineers to better navigate the business-engineering nexus is a systemic transformation of engineering education that develops the engineers' consciousness of their unique skills, their ability to understand others' perspectives and their appreciation that tensions are not simply problems to be solved logically. In the final and conclusive chapter, Anette Kolmos and Jette Egelund Holgaard analyze how engineering education tends to narrow the students' view on the evaluation of the skills that matter after graduation, and they invite educators to think collectively about a more comprehensive definition of employment skills.

In Chap. 17, Mike Murphy, Pat O'Donnell and John Jameson set out to examine Carl Mitcham's appeal to cultivate critical thinking among engineers. They review all professional engineering education programs in Ireland looking for evidence for the ways students are broadened in their education to develop different ways of thinking. Their review shows that, despite the recommendations of the accreditation bodies – which provide the means to address Mitcham's concern – the majority of engineering programs remain focused on the acquisition of technical knowledge. This resistance to change is explained partly by the issue of identity: how to transform an engineering program without losing the core identity and traditional image of what an engineer should be. This conclusion, that to date there has been only a weak opening of Irish engineering programs to non-technical topics, also indicates that such broadening is not (yet) considered as a means for the institutions to differentiate themselves from one another. In order to address the beneficial changes they perceive to be necessary, Murphy, O'Donnell and Jameson conclude that the role of accreditation panels can act as mechanisms and levers to shape engineering education. They suggest that accreditation panels should contain non-engineer members who could represent society's interest. Though hybrid programs (such as the ones they analyzed) appear to be fruitful means to address the "true Grand Challenge", they leave open the limits to the degree of hybridization in engineering degree programs in Ireland.

Following on from this chapter on the weak incorporation of non-technical topics in engineering education, in Chap. 18 Michael Dyrenfurth and Gary Bertoline study the "larger outcomes" (i.e. that go beyond "pragmatic capabilities") expected from US undergraduates from 4-year baccalaureate engineering technology programs for industry and business professionals. The larger outcomes they review are narrower than in Chap. 17, focused on ethics, corporate social responsibility (CSR) and conscious capitalism (CC). Although cited among ABET and AACBS accreditation criteria, these outcomes concern other social actors and question the very objectives of higher education. For whom does the university presently work and for whom could it alternatively work: employers, young people, civilization, a more just society? Despite the rhetoric of the decision-makers in favor of the broadening of education, the majority of US Business & Technology programs do not address the larger concerns, with the exception of professional ethics. Dyrenfurth and Bertoline, aware like Murphy, O'Donnell and Jameson, of the leverage effect of the accreditation body criteria to make programs evolve, suggest moving away from the *laissez faire* approach and adopting a more prescriptive approach for the integration of ethics, CSR and CC. They recommend that such courses should be included in the core curriculum and not simply left to the free choice of the students. They complete their review with a discussion of two innovative hybrid programs (at Olin College and Purdue Polytechnic Institute), which demonstrate the potential for pushing boundaries and building new types of professionals.

Lovasoa Ramboarisata and Corinne Gendron focus their attention in Chap. 19 on the way CSR is actually developed in a world-ranked MBA program, which attracts many students with engineering backgrounds. According to the authors, engineering ethics in a North American context (they are from Québec) do not prepare future engineer-managers for the complexity of their mission, because of the narrow focus of engineering ethics on duty to the profession. Neither are engineer-managers prepared by Sustainable Development (SD) education, which has gained attention in engineering programs all over the world, because of its almost exclusive focus on techno-ecological quantitative issues, rather than human, political and socio-economic ones. The outcome of Ramboarisata and Gendron's review was that CSR education within the MBA does not enable students to develop a better understanding of the institutional and systemic dimension of the Business-Engineering nexus. Not only are such courses still too rare but moreover they seldom go beyond the managerial micro-ethics approach (normative) and/or the mainstream utilitarian approach which assume that business interests, professional interests, and public interests are always compatible. In their conclusion they suggest that the future engineer-manager should be exposed to more SD and CSR courses offering alternative approaches to the dominant view. They support this conclusion with the description of a course they have themselves developed, following the *Ecole de Montréal* approach, based on a socio-critical perspective at the junction of the Canadian and the European scholarship.

Joakim Juhl and Anders Buch, in Chap. 20, also begin from the need to change engineering education as documented by other authors of this book and in Part IV in particular. They use the creation of a hybrid curriculum in Denmark, *Design & Innovation,* to conduct an epistemic investigation on the sociopolitical context of the emergence of interdisciplinary programs that combine problem solving skills with assessment competencies. The global context of their inquiry is characterized by new expectations of science being called upon to produce socially robust knowledge (Gibbons Mode 2) more than reliable knowledge (Mode 1), and the application of transdisciplinary knowledge to supersede purely academic interests, thus contesting the demarcation between disciplines. The local context of their inquiry was the commercial turn in Danish academia and disengagement of the Danish government in the funding of research. Paradoxically, the external constraints that weighed on the Technical University of Denmark, which might have undermined the legitimacy of engineering, gave a unique opportunity to create a new type of holistic program. The incorporation of content usually reserved for business education enabled the creation of a new legitimacy for engineering education and attracted a more diverse body of students. The program was a success and trained a new type of professionals for a decade until it lost its status of "special project" and special aid benefits from the university.

The context in which Alan Cheville and John Heywood discuss education in Chap. 21 is the one identified in the previous chapters of Part IV (commercial turn, and utilitarian view of higher education). However, the financialization of the economy is not analyzed here as an opportunity for curriculum innovation, but rather as a reinforcement factor of the engineers' hyper-specialization. Beginning with the assertion that tensions are necessary for the maintenance of organizations as learning systems, Cheville and Heywood argue that engineers often adopt a problem-focused mentality when many difficult issues are better framed as tensions. It is tensions that define organizations and societies and consequently students need navigation skills and negotiation skills, which are generally not developed in traditional engineering education programs. This lack is particularly felt when engineers (specialists) are placed in management positions and need to synthesize information framed in diverse role-specific perspectives. In such cases, they need to have experience looking at problems from a variety of perspectives and give credence to specialties beyond their own.

Building from McGregor (McGregor 1960) two models of addressing these issues are introduced here: Theory XT and Theory YT. The former articulates organization goals and uses organizational resources to achieve those goals; the latter describes an organizational ecosystem in which the diversity of perspectives, interdependence, and flow of information both define the organization and let it adapt to a changing environment. Using this model, Cheville and Heywood propose that the modern organization requires a 'complex' engineer, one who balances XT and YT attributes. More than the addition of new content, engineering education needs a systemic transformation to be more complex and to train engineers who are not only focused on the "what" and "how" questions, but also explore the "why". Cheville and Heywood invite engineering education to develop a more 'complex engineer', balancing XT and YT attributes. This balance between traditional technical skills constitutes the unique contribution of engineers in their organizations, together with a better understanding of other perspectives, in order to enable fruitful and constructive tensions. This will offer another avenue for engineers to evolve within a changing world and to face the challenges of tomorrow.

Reforming engineering education is also the focus of Annette Kolmos and Jette Egelund Holgaard in the last and final Chap. 22 of both this section and the book. They present and discuss the outcomes of parts of a large research project on engineers' employability, meant to reform engineering education in Denmark. They begin by highlighting that the literature shows an absence of consensus on the concept and definition of employability skills. They examine one study that illustrates the differences that human resource staff, graduates, and academics place on the importance of various skills. Beyond common agreement on communication, teamwork, management and problem solving, some scholars point to relevant elements aimed at purposes other than work preparation, such as professional identity and knowledge acquisition, thus aligning with a comprehensive definition favored by Kolmos and Holgaard whereby graduates are also seen as citizens and society's members. The empirical study discussed by the two authors shows that Danish students rank highest for most traditional engineering skills and lowest for "human, ethical and social" issues. They differ from American students on ethics (in US top 5, which is explained by the institutionalization of this topic in US curricula), engineering tools (in which they rank much higher), and design (in which they rank much lower). Their education path tends to strengthen their narrow view on employability and does not prepare them to address environmental, global, ethical and social issues. Like Cheville and Heywood, Kolmos and Holgaard invite engineering education to question the what, why and who, and not only the how, and they conclude with the need to redefine what really matters regarding employability, in a broader meaning.

References

Boltanski, L., & Chiapello, E. (2007/1999). *The new spirit of capitalism*. London: Verso.
Couldry, N., Gilbert, J., Hesmondhalgh, D., Nash, K. (2010). The new spirit of capitalism. *Soundings* 45. Summer 2010, ProQuest.
Klein, N. (2015/2014). *This changes everything.* UK: Penguin Books.
Mackey, J., & Sisodia, R. (2014). *Conscious capitalism: Liberating the heroic spirit of business*. Boston: Harvard Business Review Press.
McGregor, D. (1960). *The human side of Enterprise*. New York: McGrawHill.
Piketty, T. (2014). *Capital in the twenty-first century*. Cambridge: The Belknap Press of Harvard University Press.
Weber, M. (2007/1904). *The protestant ethic and the spirit of capitalism.* London: Routledge.

Steen Hyldgaard Christensen MA in Danish Language and Literature and the History of Ideas from Aarhus University, PhD in Engineering Education Research from Aalborg University. Until 2014 senior lecturer at Aarhus University. Since 2014 Adjunct associate professor at Aalborg University. He is lead editor and co-author of 6 edited volumes: *Profession, Culture, and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives* (Springer 2012), *International Perspectives on Engineering Education*: *Engineering Education and Practice in Context. Volume I* (Springer 2015), and *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context. Volume II* (Springer 2015). Besides he has co-authored *A Hybrid Imagination: Science and Technology in Cultural Perspective* (Morgan & Claypool Publishers 2011) together with Andrew Jamison and Lars Botin. In addition he has published a number of articles on engineering epistemology, culture and higher education. Current research interest: Dynamics in higher education restructuring, Thorstein Veblen, and the tension between engineering and business.

Bernard Delahousse MA in English Language and Literature, Faculté des Lettres de Lille, France. Ex-lecturer in English for Specific Purposes for Engineering students at Université de Lille – IUT « A » de Lille, France. Head of International Office at IUT "A" Lille 1 (1987–2004). Co-editor and co-author of three previous books resulting from international projects initiated and coordinated by S. H. Christensen: *Profession, Culture and Communication: An Interdisciplinary Challenge to Business and Engineering* (Institute of Business Administration and Technology Press 2003), *Philosophy in Engineering* (Academica 2007), *Engineering in Context* (Academica 2009). Co-author of a further book coordinated by S. H. Christensen: *International Perspectives on Engineering Education: Engineering Education and Practice in Context. Volume I* (Springer 2015). Chief editor of *Les Langues Modernes*, the journal of the French Association des Professeurs de Langues Vivantes (APLV), 2007–2010, then co-editor 2011–2013

Christelle Didier BS in Electrochemistry Engineering, MA in Education, PhD in Sociology from Ecole des Hautes Etudes en Sciences Sociales (EHESS) Paris. From 1993 to 2013 Assistant Professor at Catholic University of Lille, France, Ethics Department. Assistant Professor, Université de Lille, Département des sciences de l'éducation UFR DECCID. Co-author of *Ethique industrielle* (DeBoeck, Brussels, 1998) and *International Perspectives on Engineering Education* (Springer 2015); author of *Penser l'éthique des ingénieurs* (PUF, Paris, 2008) and *Les ingénieurs et l'éthique. Pour un regard sociologique* (Hermes, 2008). She has published many articles on ethics and social responsibility in the engineering profession and education, and on the engineering profession's values (from interviews and extensive surveys). Research areas: engineering ethics and values, including historical, cultural and gender perspective, sustainable development and corporate social responsibility, social responsibility.

Martin Meganck MSc in Chemical Engineering from Ghent University, PhD in Chemical Engineering and MA Moral Theology both from KU Leuven. Lecturer in Philosophy and Ethics in the Faculty of Engineering Technology at KU Leuven in Ghent. Teaching areas: Philosophy of Science, Philosophy of Technology, Professional and Business Ethics, Research Integrity.

Mike Murphy PhD and MEng degrees in electrical engineering from Stevens Institute of Technology. Prior to that he graduated with an Honours Diploma in Electrical Engineering from Dublin Institute of Technology, and BSc(Eng) Honours Degree from Trinity College Dublin. He is a Fellow of Engineers Ireland and a Member of the Institute of Electrical and Electronics Engineers. He is President of the European Society for Engineering Education (SEFI) and is past Chair of the European Engineering Deans Council. He commenced his industry career with AT&T Bell Labs in New Jersey, and later worked with Bell Communications Research before returning to the academy in 2002, when he joined Dublin Institute of Technology as Director and Dean of the Faculty of Engineering. In 2009 he accepted responsibility for the newly formed College of Engineering & Built Environment at Dublin Institute of Technology, which he led as Dean until January 2014. Mike is currently the Academic Registrar at DIT and is Director of Academic Affairs, Digital Campus & Learning Transformation.