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Engineering, Development and Philosophy

American, Chinese and European Perspectives

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Preface

In 1994, Richard B. Norgaard published *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future.* From an ecological perspective, Norgaard offered an analysis of why development has so frequently failed and the reasons why it is programmed to fail. Dating back to the Western Enlightenment, the modern project has been based on presumptions about universal human values and the idea of progress through control over nature through science, material abundance through technology, and effective government through rational social organization. However, despite resounding achievements, between the promise of modernity and its actual accomplishments, there has been a remarkable gap. Instead of fulfilling its deepest aspirations, Norgaard argues that modernity through science and technology as the main engines of economic growth has led to systematic introductions of risk, environmental degradation, population increase, poverty, social injustice, and cultural destruction on a global scale. The social acceptance of scientific ways of understanding and attempts to act rationally on these understandings has led to the exclusion of other ways of knowing, both scientific and traditional, to the detriment of a coevolutionary path to the future.

In this book, we do not unanimously claim that we share Norgaard's conclusions, but we do share and have been inspired by his co-evolutionary perspective on development and the promise of including other ways of knowing, both scientific, philosophical, and cultural. In particular, the traditional Chinese worldview derived from Confucianism, Taoism, Buddhism, neo-Confucianism, and popular religious practice provides lessons for an ecological worldview based on ideals of harmony, human perfectibility, and systemic fit within natural systems and processes. This remains true even in the presence of the distinctive successes of the Asian Four Tigers (Hong Kong, Singapore, South Korea, and Taiwan) and efforts to draw positive lessons from them by China, India, and others. The traditional Chinese worldview strongly emphasizes the interdependence of all living beings and therefore calls for a delicate balance between human wants and ecological needs. In contrast, the Judeo-Christian worldview contains deeply dualistic and individualistic values that put human beings at the center of the universe. The most extreme version of this anthropocentric paradigm is reflected in the dominant values and beliefs of consumerism. To what extent distinctive Asian worldviews can alter the Western trajectory remains an open question, one that must be addressed with something other than romantic idealism.

The coevolutionary perspective and the aspiration nevertheless to include other approaches to thought and practice take the form of cross-cultural encounters among American, Chinese, and European scholars who set out to reflect on the cultural contexts and meanings of engineering and development, well aware that development is a complex and nontrivial concept. These cross-cultural encounters can be circumscribed as efforts to grapple with three simply stated but complex questions related to American, Chinese, and European cultural contexts:

- Where do engineers come from?
- What is engineering for?
- What are engineering studies for?

The first question refers to the formation of engineers through educational systems, institutions, degree programs, curricula, courses, disciplines, and more. The latter two questions acknowledge and extend Gary Downey's work on dominant practices and scalable scholarship in *engineering studies*. Here, they more precisely refer to localized meanings and purposes of engineering and cases of critical participation within engineering and sophisticated scholarly reflection on both opportunities and discontents.

What we offer is thus a genuinely cross-cultural, inter-, and meta-disciplinary reflection by engineers, philosophers, humanists, and social scientists. The book is the result of an American-Chinese-European research project launched in Golden, Colorado, at the Colorado School of Mines in May 2010. The original idea for this workshop grew out of previous meetings in 2009 at the Graduate University of the Chinese Academy of Sciences in Beijing and Dalian University of Technology and a previous European-American project titled "Engineering in Context." Regarding the composition of the team, Carl Mitcham was in charge of selecting the American team of scholars, Li Bocong and Carl Mitcham of selecting the Chinese team, and Steen Hyldgaard Christensen of selecting the European team. The structure of the book and the contributions of participants were agreed upon at the 3-day May 2010 workshop in which 21 scholars participated. During the process, Yanming An acted in roles of mediator and translator to bridge potential gaps in understandings between Chinese- and English-speaking participants. Some further coauthors were invited to join the project following the workshop, thus raising the number of contributors to 36.

The working hypothesis and point of departure of the workshop was the shared belief that engineers and engineering are key influences in the new form of the world and experience that we as human beings are creating both locally and globally. Additionally, this creation is most commonly described in terms of development, although the concept of development is usually understood to mean quite different things in American, Chinese, and European cultural contexts. In the extension of this shared belief, some of the questions that we discussed were:

1. What does engineering mean in different contexts?
2. How does international development work challenge the professional identities, practices, designs, and ethics of engineers?

3. How does development at different levels (subnational, national, international, transnational, global) challenge engineers to engage perspectives other than their own (e.g., local communities, engineers from other countries, humanitarians, etc.)?
4. What can we learn from different cultural perspectives?
5. What is the meaning and role of sustainability in relation to engineering and development?
6. In what ways do sustainability support or challenge ideas and practices in engineering?

Inevitably, such questions relate to ongoing discussions among engineering educators regarding engineering epistemology and the proper relationship between theory and practice and interactions between "the technical" and "the social" in an engineering education deemed suitable for engineering practice in an increasingly globalized professional context.

In an extension of Andrew Jamison's historiographical work on engineering and technology and Anders Buch's analysis of dominant discourses in the literature on engineering challenges, the workshop identified three different strategies to the integration of what has been called "social," "contextual," or "nontechnical" knowledge into engineering education. Each of these strategies is characterized by a distinct set of inherent normativities. Concurrently, these strategies reflect different perspectives on development related to commercial, societal, and cultural contexts, respectively. The three strategies are:

1. A business strategy
   Aimed at optimizing local and national competitiveness and profit and securing economic welfare through a focus on the market system, companies' demand for competencies, employability, management, and technical innovation. Epistemologically speaking, here nontechnical knowledge predominantly takes the form of integrating business knowledge and business disciplines into engineering curricula.
2. A professional strategy
   Aimed at improving living conditions and securing social welfare through technological solutions that focus on macro-ethical responsibilities in relation to humankind and nature. Here, the emphasis rests on engineering virtues, professionalism, solutions that work, and "doing service" to humanity by enriching technological solutions. Nontechnical knowledge integration quite often takes the form of an endeavor to restructure undergraduate engineering as an academic discipline, similar to other liberal arts disciplines in the sciences, arts, and humanities. Strong emphasis is put on professional and disciplinary mastery with the goal of preparing students for lifelong learning rather than employment as an engineer immediately after graduation at the bachelor level.
3. A hybrid strategy
   The point of departure for this strategy is the disintegration and proliferation of technological knowledge and the emergence of techno-science. The aim is to produce new knowledge and engage with the community. Nontechnical knowledge takes the form of (a) increased context sensitivity and a concern to increase the breadth of problem scoping in engineering and (b) integration of contextual

knowledge and understanding into engineering curricula with an emphasis on social responsibility.

These three strategies and their inherent normativities will either explicitly or implicitly, individually or in combination, make themselves heard as the backdrop of the individual chapters in this book.

We would also like to emphasize the collective character of the volume. This is reflected on two levels. First, in spite of our aim to write a scholarly book allowing participants a certain degree of freedom to pursue their research priorities, it has been a central concern for all of us that the work should present itself as a coherent and integrated whole. Second, the collective character of the book is reflected in the fact that a considerable number of the 23 chapters are coauthored, a few of them even across cultural divides.

Because the book aims to further the dialogue between engineering and philosophy by exploring ways the humanities can contribute to self-development in engineering education through the appreciation of the multiple contexts within which engineers increasingly work, academics are our primary audience. However, the book also addresses a wider audience and may actually function as a means to achieve greater self-understanding for both teachers in engineering disciplines and for practitioners. Additionally, educational policy makers, on both political and institutional levels, may find valuable material for reflection and inspiration here, insofar as different chapters provide insights into what development policy makers should know about engineering. We believe that, not least, the process of globalization compels engineering educators to rethink and to recontextualize engineering education in order to educate a better and more hybrid type of engineer. Finally, we hope the book may inspire students of engineering as well as students of the humanities and social sciences who are interested in the challenges and complexities that a rapidly changing and globalized world pose for higher education in general and for engineering education and practice in particular.

The Structure of the Book

The structure of the book reflects an effort to present the individual chapters in a logical and coherent manner. At the beginning, there is an introduction which serves to frame the contents but can also be read separately. The separate chapters are grouped into three main parts, each presented and framed by its own short introduction. An abstract and a number of keywords at the beginning of each chapter support a reading overview.

In the first part, engineering and development and dialectics of good intentions are reconsidered or questioned from both philosophical and engineering perspectives. The second is focused on engineering education. This part is devoted to a comparative analysis of American, Chinese, and European perspectives on engineering education viewed from both a synchronic and a diachronic perspectives. The third part consists of a combination of comparative case studies of specific technologies, engineering leadership, and engineering ethics studies starting with a study of Engineers Without Borders, followed by a comparative study of socio-technical integration in research policies, scaling up to a general perspective on the relationship between engineering, nature, and society in the final two contributions.

The diversity of images and identities of the engineer, and the diversity of environments within which they work, is also reflected in the diversity of contributors. Historians, sociologists, and philosophers meet with "hard-core" electrical and mechanical engineers. Backgrounds in literature meet backgrounds in business administration and chemistry. The reader may feel the original backgrounds in the angle and style of the different chapters. The American, Chinese, and European origin of the authors may also be perceptible in the differences in the use of the English language. For the editors and other contributors, this variety of inputs was an enriching experience. It was also one of the starting premises of the project. We hope readers will feel and appreciate something of the experience we had when working together.

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Herning, Denmark	Steen Hyldgaard Christensen
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February, 2012	

Contents

General Introduction

Steen Hyldgaard Christensen, Carl Mitcham, Bocong Li, and Yanming An

Engineering, Cultural Value Systems, and Development

> Are there elements in China's cultural tradition which – not only for China but the world at large – can continue to live today and retain their value? Or is the difference in environment so great that, except as museum pieces, they have lost their relevancy?
>
> (Bodde 1957, p. 85)

As indicated by the titles of its three sections, this book has three aims: (1) rethinking philosophy of engineering and development, (2) rethinking engineering education, and (3) rethinking perspectives on engineering, nature, and society. The unifying intention centers on cross-cultural awareness by comparing American, Chinese, and European perspectives. In pursuing these goals, the following three major thematic issues are of primary concern: (a) China's modernization and the challenge of "sustainability" in both developed and developing countries; (b) local, national, and global normativities behind the positioning and repositioning of engineering and engineering education across the three regions and beyond; and (c) the traditional

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Chinese harmony-oriented worldview as a conceptual resource for ecological thinking and its application in specific cases of engineering ethics studies in China and in comparison with other perspectives.

Recombining chapters within and across the three sections of the book brings other themes into view. For example, a separate issue highlights China's modernization and the inadequacy of any view that portrays modern engineering in China as mainly reactive and characterized by an inability to decouple modernization from Westernization. Instead, any appreciation of the role of engineering in China must acknowledge distinctions between four historical periods of codevelopment between engineering and Chinese society:

- 1840–1919: Premodernization
- 1919–1949: Chinese nationalism and modernization
- 1949–1978: Independent development of China under communism
- 1978–2011: Reform and opening up

A dialogue with the past and the legacy of communism has played crucial roles in codeveloping engineering and modernization in the Chinese context. Other contexts with different periodizations of codevelopment between engineering and society have manifested different dialogues that can inform and be informed by the Chinese experience.

Indeed, a second theme calls attention to cultural value systems and their relevance to engineering ethics studies in America, Europe, and China. In each of these regional histories, professional engineering ethics has emerged in dialogue with distinctive cultural traditions. In the United States, the tradition of free market individualism can be found reflected in an emphasis on the responsibilities of individual engineers to avoid conflicts of interest and blow the whistle when necessary. In Europe, traditions of social solidarity have led to greater emphasis on organizational and institutional responsibilities. In the United States, for instance, ethics codes for individual engineers play a more prominent role than in any European country. In Europe, role responsibilities are more often given legal formulations that structure both public service institutions and private corporations.

In China, the problematics of traditionalism, communist nationalism, and opening up have contributed special tensions to discussions of professional ethics. Here, interactions between a traditional harmony-oriented worldview, nationalist development, and incipient globalization provide a background for multiple case study controversies. Of note in the present volume are the infrastructural development of the Chinese railway system (Chap. 20), controversies over dam construction (Chap. 19), and debates about conservation of the Chinese industrial heritage (Chap. 18). In particular, controversies regarding modern dam construction for hydroelectric generation, abundant and inexpensive water, agricultural irrigation, industrial and commercial application, and management of floods and droughts have raised ethical concerns in China such that the prospects of further dam construction are uncertain. Indeed, much is the same in the United States and Europe, which have abandoned their earlier commitments to dam construction. Is China simply repeating a historical development of the West or is it possible that China will moderate or modify its dam construction work in ways that will better the West?

Still a third theme concerns engineering education. Here, the emphasis shifts to the United States and Europe (as in Chaps. 9, 10, 11, 12, 13, and 14) but with complementary chapters dealing with the formation and leadership roles of engineers in China (Chaps. 4, 8, and 21). Taken together, such discussions disclose multiple trajectories for reform in engineering education across the three regions. They also make it abundantly clear why governing and reforming engineering education by relevant constituencies is so extremely complex.

Finally, the concluding two contributions (Chaps. 22 and 23) may be read as a dyad centered on the cultural origin and nature of, and differences between, the traditional Chinese harmony-oriented versus the Judeo-Christian domination-oriented worldviews. These two discussions are in some sense foundational for framing analyses of environmental degradation, of the historical roots of our present ecological crisis, and of principles of sustainable development. In dealing directly with the classical texts of the respective cultural backgrounds, these reflections present a fuller and more detailed portrait of the ambiguous social role of engineering, science, and technology in Asian and Eurocentric cultures.

Since the 23 chapters of the book and the links between them are presented in some detail in the three section introductions, this general introduction has broader aims. By way of providing deeper background for particular discussions, it considers three issues: neoliberal regimentation of globalization and development, emerging concerns in engineering and engineering ethics studies in China, and post-neoliberal engineering-for-development initiatives that seek to incorporate social justice goals and the often contradictory dialectic of "good" intentions.

Neoliberal Regimentation of Globalization and Development

> Neoliberalism seems to be everywhere. This mode of free market economic theory, manufactured in Chicago and vigorously marketed through principal sales offices in Washington DC, New York, and London, has become the dominant ideological rationalization for globalization and contemporary state "reform."
>
> (Peek and Tickell 2002, p. 380)

Development is predicated on the assumption that some people and places are more developed than others, and therefore, those who are "developed" have the knowledge and expertise to help those who are not (Kothari 2005, p. 427). In terms of a center periphery of power distinction, this assumption ultimately implies that the center of power is identical with the center of truth (Nederveen Pieterse 1991, p. 5). Although problematic, such assumptions continue to prevail in much development thinking related to the ideology of modernization and tend either consciously or unconsciously to be embodied in the ideas, authority, and practices of the development *expert* (for a more detailed discussion of a global development ethic see

Chap. 6, Kothari 2005; Nederveen Pietersee 1991, 2010). According to Franz Schuurman (2000, p. 8), in the wake of World War II, all development thinking shared in at least three beliefs:

1. The essentialization of the third world and its inhabitants as homogeneous entities
2. An unconditional commitment to the concept of progress and the makeability of society
3. The importance of the (nation) state as an analytical frame of reference and a political and scientific confidence in the role of the state to realize progress

Among a number of other contributing factors, globalization has forced the qualification of these beliefs. In itself, globalization was propelled by rapid advances in transport, communication, and information technologies. In the long nineteenth century, globalization took place primarily through European and North American colonization and the economic activities of nation states. In the second half of the twentieth century, nation-state globalization was subsumed into transnational political entities such as the United Nations and NATO with increasing competition from multi- and transnational corporations such as Adidas and Niké (shoes), Siemens A.G. (industrial equipment), Microsoft (software), and Nestlé (foods). The energy and telecommunications sectors of the economy could provide further examples. Thomas Friedman (2007) has characterized these nation-based and corporate-based processes as globalization 1.0 and 2.0, respectively. He has further argued the existence of a new form of globalization 3.0 based in individuals: entrepreneurs, musicians, athletes, and others who themselves become global actors. One might also suggest that scientists and engineers are increasingly representatives of globalization 3.0, which nevertheless remains highly subject to the structures of neoliberal governmentality.

According to Trent Hamann (2009), neoliberal governmentality is rooted in entrepreneurial values such as competitiveness, self-interest, and decentralization. Its central aim is

> the strategic production of social conditions conducive to the constitution of *Homo economicus*, a specific form of subjectivity with historical roots in traditional liberalism. However, whereas liberalism posits “economic man” as a “man of exchange,” neoliberalism strives to ensure that individuals are compelled to assume market-based values in *all* of their judgments and practices in order to amass sufficient quantities of “human capital” and thereby become “entrepreneurs of themselves”. Neoliberal *Homo economicus* is a free and autonomous “atom” of self-interest who is fully responsible for navigating the social realm using rational choice and cost-benefit calculation *to the express exclusion of all other values and interests.* Those who fail to thrive under such social conditions have no one and nothing to blame but themselves.
>
> (Hamann 2009, p. 38)

Neoliberal governmentality thus celebrates the empowerment of the individual, the downsizing of government, and the decentralizing of state power to smaller localized units. The neoliberal mode of governance promotes the self-regulating free market. Citizens who pursue the common good along traditional lines, striving to enhance civil society and social justice, are redefined as customers striving in this capacity to maximize their self-interest vis-à-vis the public (Steger and Roy 2010, p. 12).

According to Erhard Berner and Benedict Philips (2005), the apparent efficiency of this governmentality is the foundation of its influence (the shortcomings of Keynesian style controlled capitalism in the 1970s having led, it is argued, to the creation of self-serving state bureaucracies and economic stagflation). Its underlying goals of cutting subsidies and transfers for public welfare and development made it popular among conservative governments, bilateral and multilateral development agencies, and international financial institutions such as the World Bank and the International Monetary Fund (IMF). However, James Petras and Henry Veltmeyer (2002) have accused "foreign aid" neoliberalism of being a catalyst for regression. They distinguish between two approaches to aid – realist and idealist – and possible hybrid combinations thereof. The predominant realist approach requires the payment of both principal and interest on loans from international financial institutions, with devastating impacts on policy-making and living conditions in developing countries. To obtain such largely short-term loans, recipient countries are required to adhere strictly to the so-called Washington Consensus formulated in the 1980s by the IMF, World Bank, and US Treasury.

The Washington Consensus itself grew out of the postwar international economic order established by a 1944 conference in which representatives from 44 allied nations gathered at the Mount Washington Hotel in Bretton Woods, New Hampshire. Dominated by Harry Dexter White (1892–1948) and John Maynard Keynes (1883–1946), the Bretton Woods agreements created the IMF and the World Bank along with the momentum that led to the General Agreement on Tariffs and Trade (GATT), which eventually was transformed into the World Trade Organization (WTO). The Washington Consensus can be read as a critical reformulation of the Bretton Woods system. In brief, as a policy package, Washington Consensus neoliberalism promotes (as summarized by Williamson 1989):

1. Privatization of public enterprises
2. Deregulation of the economy
3. Liberalization of trade and industry
4. Massive tax cuts
5. "Monetarist" measures to keep inflation in check, even at the risk of increasing unemployment
6. Strict control on organized labor
7. The reduction of public expenditures, particularly social spending
8. The downsizing of government
9. The expansion of international markets
10. The removal of controls on global financial flows

This approach is seen by Petras and Weltmeyer as a catalyst of "reverse aid" designed to benefit the donor countries. In support of Petras' and Veltmeyer's position, the 2001 Nobel Prize winner in economics Joseph Stiglitz writes:

> The Western countries have pushed poor countries to eliminate trade barriers, but kept up their own barriers, preventing developing countries from exporting their agricultural products and so depriving them of desperately needed export income…. It not only hurt the developing countries; it also cost Americans, both as consumers, in the higher prices they paid, and as taxpayers, to finance huge subsidies, billions of dollars.
>
> (Stiglitz 2002, pp. 6–7)

By contrast, the idealist approach conceives of aid as a disinterested policy unrelated to the interests of financial capital and guided exclusively by humanitarian concerns, democratic values, and economic well-being. However, in many cases, the idealist approach tends to neglect its own embedding in a specific historical-structural context. The idealist approach emphasizes normative values but does not always critically assess the degree to which these values may be influenced by other interests or not complied with in aid-receiving countries.

It is also important to notice the transformative and adaptive capacity of the far-reaching political-economic neoliberal project. Making a distinction between destructive and creative moments of neoliberal reform, Jamie Peck and Adam Tickell (2002, pp. 388–389) argue that neoliberalism does not unfold following a universal scheme but in localized forms with differential combinations of state, cultural context, and market and in terms of "rollback" or "rollout" neoliberalism. As a consequence, neoliberalism has many different trajectories. There are major differences among American, Chinese, Russian, and Danish trajectories of "rollout" neoliberalism.

According to Wendy Larner (2000), besides governmentality and a policy package, the term neoliberalism also denotes an ideology. Manfred Steger and Ravi Roy (2010) argue that the ideological codifiers of neoliberalism are global power elites consisting of managers and executives of large transnational corporations, investment bankers, corporate lobbyists, influential journalists, public relation specialists, intellectuals, economists, celebrities, top entertainers, state bureaucrats, and politicians. As advocates of neoliberalism, they serve its agenda in saturating the public discourse with idealized images of a consumerist, free market world. "Skillfully interacting with the media to sell their preferred version of a single global marketplace to the public, they portray globalizing markets in a positive light as an indispensable tool for the realization of a better world" (Steger and Roy 2010, p. 11).

Since the financial crisis that broke out in 2008 and has continued into 2012, it has become increasingly clear that neoliberalism has not been able to deliver on its promises. Markets were not self-correcting and governed by an Adam Smithian "invisible hand." Neither did they automatically emerge as the natural order by themselves without strong support from the state. Tax cuts and deregulation of financial markets have instead contributed to the creation of social injustice and inequality of tremendous proportions, both nationally and globally. According to Stiglitz:

> The world has not been kind to neo-liberalism, that grab-bag of ideas based on the fundamentalist notion that markets are self-correcting, allocate resources efficiently, and serve the public interest well. It was this market fundamentalism that underlay Thatcherism,

> Reaganomics and the so-called "Washington Consensus" in favor of privatization, liberalization, and independent central banks focusing single mindedly on inflation. For a quarter century, there has been a contest among developing countries, and the losers are clear: countries that pursued neo-liberal policies not only lost the growth sweepstakes; when they did grow, the benefits accrued disproportionately to those at the top.
>
> (Stiglitz 2008, p. 1)

The current crisis of development is therefore both a crisis of neoliberal development in the global South and a crisis of neoliberal globalization in the West. In the West, neoliberal globalization is being challenged by new social movements, "Occupy Wall Street" being only among the more recent. In the global South, alternative development strategies now test the limits of the ideology of modernization (Nederveen Pieterse 1991). Ultimately, the current situation may be conceived of as a crisis of financial market capitalism itself. According to Michael Brie (2009, pp. 20–22), the current crisis of financial market capitalism is unfolding in five dimensions, posing a threat to its continued existence in the present form. Brie's descriptors are abbreviated and summarized below:

1. *A crisis of overaccumulation*. Valorization of capital investment and development necessities are fundamentally different.
2. *A crisis of social reproduction*. There is a tendency in financial market capitalism to shorten capital valorization to 2 years. As a result, there is a general underinvestment in the renewal and development of the most important fields of social reproduction, in particular in education, culture, environment, and health.
3. *A crisis of social integration*. Worldwide, the decay of the state has reached 25% of all countries. There are now over 20 million refugees worldwide. There are three billion humans in need of basic essentials such as sufficient nutrition, fresh water, minimal sanitary conditions, medical help, and education. In many countries, either the social state or the traditional institutions of social integration are being destroyed.
4. *A crisis of democracy*. Never before have there been so many free elections as today, while at the same time, the expectations attached to them of a social and economic development that corresponds to these interests have been followed by disappointment. This means that there are crises in both the rationality and legitimacy of the political system of representative democracy.
5. *A crisis of security*. Water, raw materials, access to the sea, migration, knowledge, capital, and cultural identity – in neoliberalism, anything and everything becomes not only a commodity but also a cause of competition and violent confrontation. With the globalization of capital, violence has also been globalized.

Emerging Engineering Studies in China

> In the first years after the 1949 Chinese Revolution, economic and cultural capital were concentrated in the hands of the old elite classes, while political capital was concentrated in the hands of the new Communist elite, made up largely of peasant revolutionaries. The new

> regime first redistributed economic capital, dispossessing the old elites and converting the means of production into state and collective property… Having virtually eliminated economic capital, the CCP turned its attention to redistributing cultural capital, with the intention of further undermining the advantages of the old elite, an endeavor that reached its most radical point during the Cultural Revolution… After Mao's death in 1976, the new CCP leadership renounced class leveling and reconciled with the old elite. This facilitated the consolidation of a technocratic class order and the emergence of a New Class [of red engineers].
>
> (Andreas 2009, p. 11)

As the most populous and rapidly developing country in world history, the People's Republic of China (PRC) – which across the twentieth century experienced more wrenching social change than any other state – is home to large-scale engineering achievements and sobering disasters. In the tradition of the Great Wall and Grand Canal are the Three-Gorges Dam (see Chap. 19) and a system of high-speed trains more extensive than the rest of the world combined (see Chap. 20). At the same time, in 1975 the Banqiao Reservoir Dam collapse caused more casualties than any other dam failure in history; in 2009, a whole 12-story apartment building on the outskirts of Shanghai toppled over due to a foundation failure; and in 2011, two high-speed trains collided in Zhejiang Province, causing the second deadliest such accident in the world. Environmental pollution is the worst of any developing country and has impacts far beyond China's borders.

Reflecting the large role of engineering in China today, probably more engineers occupy political leadership positions in the Chinese Communist Party and PRC than is the case in any other government. The closest comparison in United States history is the period when Herbert Hoover was elected the first engineer president (1929–1933).There is also more discourse on the ethics of science and engineering than in any other developing country as well as than in any other country in history at a comparable stage of technological development, including the first third of the twentieth century in the United States. During the 1990s, for instance, the Graduate University of the Chinese Academy of Sciences (GUCAS) established a program on the philosophy of technology and engineering and subsequently founded the Chinese journal *Engineering Studies* (2004–present). Under the leadership of Li Bocong, the program has expanded into a practice-oriented program in the philosophy and sociology of engineering broadly construed. As Li argues (2010, pp. 37 and 39), the "engineering community comprises [not only] engineers [but also] managers, investors, workers, and other stakeholders." Moreover, since "philosophy is above all about how to lead a better life with wisdom," in the contemporary world, this calls for reflection on "the wisdom of engaging in engineering activity." This theme of integrating wisdom into engineering is reflected especially in Chaps. 3, 5, 18, and 22.

Additionally, in 2007, scholars from leading engineering universities established the Chinese Society for Ethics of Science, Technology, and Engineering based at Dalian University of Technology. Engineering ethics discourse in these contexts struggles with tensions inherited from pre-communist China (efforts to overthrow feudalism and colonialism), years of dominance by Mao Zedong (red over expert), and opening up under engineer Deng Xiaoping (rapid economic development and globalization). As one young scholar has described the situation (Zhu 2010, pp.101 and 104), "engineering and engineering ethics studies in China [are drawing] on resources from China's long cultural history, reconstructing the Marxist social criticism of technology, and learning from European and North American intellectuals" to ask: How can science, technology, and engineering best contribute to enhancing Chinese ways of life? What is the most ethical way to deal with the social and environmental problems that often arise from technological and engineering change? How can we avoid engineering mistakes while promoting Chinese economic development? Working with such questions, Chinese scholars have a "responsibility to think globally and to rethink locally in order to redefine the significance of 'made in China'."

There have been complaints that things are "poorly made in China" (Midler 2009). But this charge fails to appreciate how after more than 200 years of imperialist challenges, China could only have been expected to develop some asymmetric business tactics. To complain that Chinese industrialists often go "out of their way to manipulate product specifications to widen profit margins" (Midler 2009, p. xvii) neglects to acknowledge the heritage of duplicity of European and American behaviors toward China and the rationalized duplicity inherent to productive systems in the West.

What is being made in China today is in fact something more than material products, a point that can be indicated in part by enlarging the understanding of capitalist production. Going beyond classical (non-Marxist and Marxist) analysis, capital in a generalized sense includes any human product that enhances a person's power to perform other economically useful work. Within this framework, Pierre Bourdieu (1986) has distinguished cultural and social capital. Adapting Bourdieu, Joel Andreas (2009) has described ongoing shifts in economic, cultural, and political capital. For Andreas, since the death of Mao, the peasant cadre political capital has been progressively eclipsed by the cultural capital of engineering expertise. But perhaps more than is commonly recognized, engineering expertise itself is also being remade in China – with global implications.

Post-Neoliberal Engineering-for-Development Initiatives

> It is precisely the groundswell of *anti-development* thinking, oppositional discourses that have as their starting point the rejection of development, of rationality, and the Western modernist project, at the moment of purported Washington consensus and free-market triumphalism, that represents one of the striking paradoxes of the 1990s. Ironically, however, both of these discourses – whether the World Bank line or its radical alternative – look to *civil society, participation, and ordinary people* for their development vision for the next millennium.
>
> (Mohan and Stokke 2000, p. 247)

Since the beginning of 1990s, globalization has become the new context for engineering and engineering education in the United States, Europe, and elsewhere. Engineering-for-development initiatives should therefore be seen in the light of competing ideologies of globalization. Among the most important are what may be termed market globalism, social justice globalism, and restorative justice globalism. Market globalism is characteristically promoted by the United States and sees globalization as primarily a process of expanding the free market and lowering international trade barriers, both to some degree preserved by US military power. Social justice globalism is more typically promoted by European countries and stresses the extent to which globalization is a political process that promotes human rights and international law; to the extent that military force plays any role, it must be exercised through the United Nations or some other multilateral mechanism. Restorative justice globalism takes the notion of restorative justice from the domestic sphere, where it refers to a focus on the needs of victims, offenders, and engaged communities instead of attempts to satisfy abstract legal principles, and extends this to international affairs. China, for instance, tends to see globalization as a process in which to reaffirm long-denied sovereignty and to redress historical wrongs.

There are also, of course, various antiglobalization ideologies. Manfred Steger (2009), for instance, uses the term "jihadist globalism" to refer to struggles against both market globalism and social justice globalism in the name of allegedly Islamic values and beliefs perceived by adherents to be under attack by forces of secularism and consumerism. But in fact, any globalism opposes itself to others and thus constitutes at once both an anti- and a pro-perspective on globalization as a whole.

In the present context, the focus is mainly on post-neoliberal engineering-for-development initiatives that seek to incorporate social justice goals. However, as Giles Mohan and Kristian Stokke (2000) have indicated above, it should be noticed that the move toward conceptualizing global engineering-for-development initiatives in terms of "community development," "participatory development," and "empowerment" or the other way around can be deceptive, since it has produced high-level agreements between actors and institutions of the new "left" and the new "right," although for quite different reasons. This is an indication of diversity but also of tensions between commercial, professional, and hybrid approaches to development.

In recent years, there has been an explosion in global-development-engineering initiatives in engineering education in the United States and elsewhere driven by a broad range of goals including addressing basic human needs, working to end poverty, providing students with cross-cultural design experience in preparation for careers in the globalized economy (Riley 2007). Similarly, engineering-for-development initiatives that seek to incorporate social justice goals have emerged in engineering communities around the globe (see, e.g., Riley 2008; Baillie and Catelano 2009; Catelano 2007). According to Donna Riley (2007), a broad array of models has been employed for this purpose, both curricular and cocurricular models. These models have been employed in collaboration with foreign governments, educational institutions, or nongovernmental organizations. Moreover, entrepreneurial, sustainable, appropriate technology, and/or community-based approaches to design have been applied. These initiatives seek to imagine new models of interactions with indigenous people and local cultures able to counteract adverse effects of development interventions more effectively (Nieusma and Riley 2010).

Since the beginning of the 1990s, engineering activities dealing with humanitarian engineering, community development, and service learning have surged within engineering communities in the USA and around the world. According to Juan Lucena et al. (2010) and Carl Mitcham and David Muñoz (2010), it was the involvement of other professions in humanitarian relief such as Doctors Without Borders (1971), Reporters Without Borders (1985), and Lawyers Without Borders (2000) that prompted engineers to take up the challenge leading to the establishment of a number of groups in France in the late 1980s (see Chap. 16 in this respect), Spain (1991), Canada (2000), Belgium (2002), Denmark, and others, under some national form of the name "Engineers Without Borders." Simultaneously, there has been a growing interest among engineers in trying to address the challenges of sustainable development (see Chaps. 1, 5, 10, 11, and 23 for a more comprehensive account of the historical background for the emergence of sustainable development and other challenges to and for engineers).

According to Lucena et al. (2010), the convergence of three historical key events stimulated a growing interest in humanitarian relief and sustainable development in the USA (Lucena et al. 2010, p. 40):

- The globalization of US engineering education
- The transformation of long-term loyalty to engineering employees
- The unparalleled media coverage of humanitarian crises, violent conflict, poverty, and environmental degradation occurring worldwide

Globalization has been recognized within engineering education in the USA and elsewhere both as a new business need and as a professional or social responsibility concern (see, e.g., Downey and Beddoe 2011). Simultaneously, it has been included among the ABET (Accreditation Board of Engineering and Technology) EC2000 criteria. Under criterion 3, the global context is reflected as a requirement for engineers to obtain "the broad education necessary to understand the impact of engineering solutions in a global and societal context."

One example of a course that seeks to meet this ABET requirement is the "Engineering and Global Development" course offered at Smith College's Picker Engineering Program. Its objectives and pedagogy are designed to enable engineering students to (Riley 2006, p. 51):

- Design and build technology systems for use in developing countries
- Apply knowledge of appropriate technology and its critique to design
- Critically analyze issues related to the use of technology in developing countries
- Demonstrate understanding of the limitations of technology in addressing problems of development

In this course, specific attention and critique is centered on the "expert" model.

Similar courses or programs may be found in many other places across the USA. The University of Colorado at Boulder, for example, offers a program in

Engineering for Developing Communities with a similar mission: “to educate globally responsible students who can offer sustainable and appropriate technology solutions to the endemic problem faced by developing communities worldwide (including the US).”

The crucial question is whether these initiatives have succeeded. As suggested by the term “voluntourism,” voluntary work among engineering students might sometimes entail incentives for tourism in exotic places, making their projects “hit and run” style development projects without any real value for beneficiaries. Actual contributions to the development process of a country only happen when engineers or prospective engineers are truly alert to the importance of contextual sensitivity and listen to the desires of those they are attempting to serve (Parsons 1996). In arguing in favor of a participatory model of interaction which they term negotiated development, the authors of Chap. 6 offer a more in-depth treatment of some of the complexities of the development process.

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Part I
Rethinking Philosophy of Engineering and Development

Introduction

Erich W. Schienke and Brent K. Jesiek

Whether serving directly or indirectly; whether aligned with local, national, or global interests; whether mobilized in support of defense, infrastructure building, technological innovation, or technocratic planning, engineers have long served as agents of development. As a result, their work frequently occurs at the intersection of numerous, competing normativities, or different views of how the world ought to be, what is judged good or bad, how things are valued and why. These normative claims necessarily ebb and flow over time; they proliferate and contract, forcing engineers to periodically reposition themselves and their work in relation to larger social, economic, political, and cultural forces. Engineers are at once instigators and reactants in a variety of developmental milieus.

Among contemporary development discourses challenging engineers, sustainability stands out as particularly ascendant and influential, especially as it makes its way into engineering courses and curricula, transforms engineering design practices, and begins to refashion entire industries. Yet the very notion of sustainable development is paradoxical in light of at least three tensions. The first tension rests on the paradox that continuing current national and global development practices will simply not suffice in addressing the projected growth in demand, nor adequately reduce impacts on the environment and human populations. A second key tension is that economic development itself does not imply a leveling off, in that a well-reasoned articulation of the ends is elusive and difficult to imagine, let alone capable of being signified by objective means. A third tension comes in thinking that development is somehow singular, that is, one pattern we will eventually fall into if only we can develop our ability to manage the complexity of "the system."

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Instead, it is perhaps better to recognize the desired ends as being able to produce "developments that sustain," which would force recognition that we will always need to adapt and innovate our approaches to development in economic, social, and environmental terms. The means to achieving those developments will require significant contributions from engineering and science, as well as social policy, ethics, philosophy, and political theory. Each of the chapters in Part I provides a tool – some piece, dimension, case, or framework – for helping us think through "developments that sustain." Our image of "developments that sustain" intentionally tends to resist holism or completion, and the chapters of this part (as well as the entire book) likewise resist representing some sort of whole. However, they do allow us to glimpse many of the larger pieces, actors, and frameworks for articulating new approaches to "development," including several possible roles for engineers and engineering.

Li's contribution to the volume, Chap. 2, is particularly effective in revealing the potential breadth of inquiry one may face when undertaking studies of engineering, even when the scope is narrowed, for example, to the domain of engineering and development. Drawing on a rich array of literature representing both philosophical and sociological perspectives, Li argues that overreliance on micro- and/or macro-level investigations of social phenomena may place unnecessary blinders on our analytic vision. As an alternative, he proposes a framework that can accommodate micro-level studies of individual persons and organizations, meso-level investigations that might encompass entire industries or localities, and macro-level scholarship that cuts across much larger swaths of geographical and conceptual territory. The author also notes how engineering "facts," "acts," and "results" tend to cut across all three levels, thereby encouraging us to reflect on some of the key themes running through the other chapters in this part, even though they cover a diverse range of topics and engage social phenomena across the micro-meso-macro spectrum.

In Chap. 1, for example, Jamison deftly performs Li's admonition to traverse the micro, meso, and macro, providing evidence and examples from each level to describe changing relations between engineering and development from the postwar period to the present. Drawing our attention to a number of tensions and ambiguities surrounding sustainable development, Jamison surveys a wide range of possible engineering responses to sustainability challenges, including those driven by market forces, technological innovations, and scientific research. Ultimately, however, he writes in favor of cultivating a "hybrid imagination" among current and future engineers, allowing them to meld their scientific and technical expertise with social and environmental awareness as they work to address a proliferation of global grand challenges. His discussion of the Alley Flat Initiative is presented as a leading example of how activists and academics might partner to address local community challenges, in this case providing sustainable, affordable housing alternatives in Austin, Texas. In short, engineers with hybrid imaginations are urgently needed to help establish and contribute to such projects and programs, thereby promoting what we refer to here as "developments that sustain."

Still another key dimension of the hybrid approach to engineering advocated by Jamison centers on cross-cultural awareness. This argument is given further credence by Wang and Zhu in Chap. 3, which highlights how characteristically Chinese patterns of thought have inflected the modern practice of engineering in China. In addition to standing as an important and groundbreaking contribution to a growing body of scholarship on different national "cultures" of engineering, their chapter also reveals many normative possibilities long marginal in Western discourses on development. For example, Chinese culture has traditionally placed a high value on social and environmental harmony, a theme that resonates with many contemporary discourses on sustainability. In fact, similar ideas are echoed in other recent commentaries proposing that answers to China's current ecological crises might be found in Daoism and other Eastern belief systems. The chapter is replete with specific examples that illustrate such themes, from ancient marvels like the Dujiang irrigation system to more modern cases like the Anshan Steel Company.

As made apparent to the West by scholars such as Joseph Needham, China does indeed have a long, proud, and culturally infused history of civil engineering, technological invention, and creative problem solving. However, that such a historically innovative culture never realized the scientific or industrial revolutions often leads to a picture of a modernizing China that is relatively static or at best reactive, based largely on the one-way adoption of engineering normativities from the West. Chapter 4 provides further historical analysis of the dynamic emergence of engineering in China as authors Hong and Ma challenge the externalist (and mainly American) theory of "Impact (from the West) – Response (by the East)" that views the development of modern engineering in China as mainly reactive and set against a static and unchanging culture that cannot decouple modernization from Westernization. In line with Wang and Zhu's approach, Hong and Ma argue that scientific and technological capacity in the late nineteenth- and twentieth-century China emerged based mainly on internal pressures to modernize, develop, and innovate. This "Challenge (internal to China) – Response (external and internal)" model can be observed through four distinct periods: (1) late Qing dynasty (1840–1919), when traditional Chinese knowledge (Confucianism) was embraced as the "body," while Western ideas and technologies were adopted only for their "uses" (a utilitarian approach); (2) Nationalist period (1919–1949), characterized by shifts away from traditionalism and toward modernization and Westernization; (3) Mao era (1949–1978), featuring the march of the PRC toward science and the Four Modernizations; and (4) post-Mao era of reforms (1978–present), defined by achieving significant modernization and then transitioning toward sustainable development. In taking this approach, Hong and Ma demonstrate how Chinese normativities of development shifted over different historical eras, leading to the current direction toward a "global normativity" of sustainable development.

Zooming in on contemporary challenges facing China as a developing and rapidly urbanizing nation, Schienke suggests in Chap. 5 that one significant response can be seen in plans to develop ecological cities (or "ecocities") as a key mechanism for achieving a "harmonious society." Schienke argues that in the experimentation and articulation of "the Chinese ecocity" model(s), an ethos emerges that determines the goals of the dynamic (and yet to be realized) ecological urban master plans and ecocity indicators for China's sustainable development. Providing examples from various ecocity projects in China, both attempted and in the works, the chapter demonstrates how different projects produce their own (and often competing) interpretations of ecocity indicators, outcomes, and goals. The construction of the key indicators used to determine "ecocitiness" typically are dependent on the relationship between relevant project organizations and larger normativities of State development, such as President Hu Jintao's vision of a "harmonious society." Pointing out an essential problem of taking ecocities seriously (beyond mere greenwashing), Schienke suggests that the consideration of ecosystems in urban planning requires the inclusion of normative outcomes for all connected ecological systems, internal and external to the city itself. Doing so will require ecocity planners to adopt a form of planning driven by eco-cosmopolitanism, requiring both very global (beyond the scope of China) and very local considerations of impact, protection, and inclusion.

Paying attention to good participatory development practices at the local level, while at the same time drawing effectively and measurably on international expertise, resources, and education, can produce processes by which development itself becomes a necessarily negotiated output of all of these contingencies. In response to the highly technocratic approaches to development of the late twentieth century, which often imposed locally contested approaches to development, McEvoy, Grimson, and Grimson argue in Chap. 6 that if a "good global development ethic" is to be people-centered, development project planning and decision-making must necessarily be proactively negotiated. In drawing on lessons learned from various projects in Kenya, the authors demonstrate the unnecessary hardships faced when non-negotiated development practices fail to include local interests and priorities – perspectives that are difficult to comprehend through "hard" technical expertise alone. Further, the lasting impacts of techno-social development cannot be sustained locally or over a longer duration without significant investment in higher education (HE) capacity. HE is also recognized as a key factor in improving local capacity in self-directed decision-making and in building the meritocratic self-confidence of local institutions. Like in most developing contexts, however, HE is an expensive prospect that requires focused attention toward social as well as technical capacity building. Thus, the training of local advocates to understand the complex interactions between various parties requires that the international institutions funding development projects take into account the importance of increasing HE capacity across various sectors. In addition, HE becomes the main process or forum by which the negotiation of local and global development interests can happen. And while McEvoy, Grimson, and Grimson note that many sectors require further education, engineers and engineering education are at the center of negotiated development precisely because engineering is central to so many developments and because, as a matter of training, engineers must take ethical and social matters into account alongside the technical.

Each chapter in this part presents a picture of competing normativities of engineering, often between local and global interests. While competition in development often drives improvements in coverage and depth of normative considerations, it does not do so without having made some mistakes. Drawing on historical and contemporary examples, a series of prescriptive suggestions emerge from this collection that point toward the benefits of negotiated development processes that work in conjunction with micro, meso, and macro interests of organizations, institutions, and countries.

Thus, the overarching normative project that emerges for global engineering is definitively focused on sustainability in local, national, and global contexts. However, creating “developments that sustain” is a project that by definition withstands completion. The chapters of this part (as well as the entire book) therefore resist holism while at the same time help us identify and think through some of the larger pieces, actors, and frameworks for better articulating the kinds of “development” we so eagerly seek.

Chapter 1
Turning Engineering Green: Sustainable Development and Engineering Education

Andrew Jamison

Abstract Since the 1970s, the relations between engineering and development have changed significantly. On the one hand, at a discursive or macro level, there has been a shift in regard to the kind of development to which engineering is meant to contribute, from furthering economic growth to an approach to development that is "sustainable" in one way or another. On the other hand, on a practitioner, or micro level, there has been a change in the kinds of competence that engineers are expected to have in order to be able to contribute to development, due to the emergence of new fields of "technoscience" blurring the boundaries between what was previously considered science and what was previously considered technology. Finally, in between, at an institutional or meso level, there have been significant changes in how engineering work and engineering education are organized. This chapter attempts to provide an overview of these changing relations between engineering and development and distinguishes between three ideal-typical educational responses: a technical, market-oriented approach; a scientific, academic-oriented approach; and a hybrid, socially oriented approach.

Keywords Development • Engineering • Environment • Education • Sustainability • Hybrid imagination

Introduction

Since the 1970s, there have been a number of significant changes in the relations between engineering and development. On a discursive or macro level, there has been an overarching shift in regard to the kind of development to which engineering

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is meant to contribute, from one that is primarily oriented to furthering economic growth and science-based material progress to an approach to development that is “sustainable” in one way or another. There have, however, been fundamental disagreements in regard to what a sustainable development might actually mean (Mitcham 1995; Jamison 2001).

Many, if not most, of those who make decisions and policies about development and engineering have tended to see sustainable development primarily as a continuation of economic growth by other means – a kind of “greener” or “cleaner” kind of growth – and have translated sustainability into the language of business and management, while others have seen the sustainability challenge primarily in professional, or academic terms, and have thus sought to develop new fields or subfields of sustainable science and technology within engineering and engineering education. Still others see the challenge as intrinsically human and political, requiring a fundamental reconstruction of science, engineering, and society, and have thus called for a more active integration of social and cultural understanding into the education of scientists and engineers (Jamison et al. 2011).

While the discourses of development have been getting greener, at least rhetorically, on a practitioner or micro level, there have arisen a number of other challenges to engineering and engineering education stemming from what has been termed “technoscience” – or a new “mode” of knowledge production. As Michael Gibbons and his coauthors characterized the situation in their influential account in the 1990s, scientific research and technological development are increasingly being carried out in a “transdisciplinary” manner (Gibbons et al. 1994). The boundaries that had previously distinguished scientific research, or philosophical-theoretical knowledge – what the Greek philosopher Aristotle famously referred to as *episteme* – from technological development, or practical-technical knowledge (Aristotle’s *techné*) have been blurred or transgressed in many, if not most, fields of contemporary science and engineering. In such newer domains of knowledge production such as electronics and communications, health and agriculture, energy distribution and environmental protection, and, more recently, multimedia, the nanosphere, and synthetic biology – as well as in many traditional fields – there is no longer a clear line of demarcation between scientific “theory” and technological “practice.” What Gibbons and his coauthors have called a new mode of knowledge production or “mode 2” is “knowledge which emerges from a particular context of application with its own distinct theoretical structures, research methods, and modes of practice but which may not be locatable on the prevailing disciplinary map” (Gibbons et al. 1994, p. 168). The coming of technoscience, or mode 2, thus raises important questions about what engineers need to know and how they are to learn and be taught.

In between the discursive and practitioner levels on what might be termed an institutional or meso level, there have been significant changes in how engineering work and engineering education are organized, due to the permeation of science and technology into ever more areas of our economies, our societies, and our everyday lives. For the most part, engineering is now carried out in less permanent structures than in the past, in temporary or ad hoc groups or networks, in which engineers collaborate with people from other parts of society. In both actual and virtual reality, university-based or academic engineers work ever more often together with corporate employees and government officials on particular projects in what has been called a "triple helix" linking the state, the market, and the academy in weblike relationships (cf. Etzkowitz and Leydesdorff 1997). To be able to work effectively in these new organizational frameworks requires new kinds of design skills and forms of communicative competence on the part of engineers, and most importantly perhaps, a more ambitious understanding of societal processes than engineers have previously received in their education.

In the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED), we have taken our point of departure in these three very different sorts of challenges that confront engineering and engineering education:

- The sustainability challenge, or the overarching need for scientists and engineers – as well as for humanity in general – to relate to the problems brought to light in the debates about environmental protection, resource exploitation, and climate change
- The technoscience challenge, the mixing in many fields of contemporary science and engineering of scientific knowledge and engineering skills in new combinations
- The various societal challenges, due to the permeation of science and technology into society, and calling for socio-technical competencies and a sense of social responsibility on the part of scientists and engineers

Experiences throughout the world, as well as in Denmark, have shown that it is difficult to meet these rather different challenges in a comprehensive way. Rather, a tension or contradiction has emerged that has served to pull engineering and engineering education in different directions – into a wide variety of efforts to foster a new kind of global or commercial engineering identity, on the one hand, versus a reinforcement of more traditional professional roles and academic identities, on the other.

The main response to the challenges has tended to be "market-driven" and has sought to convert the challenges into commercial opportunities in accordance with the new precepts of "academic capitalism" (Slaughter and Rhoades 2004). In regard to the educational curriculum, this strategy has meant that many engineering programs have come to include courses and instruction in such areas as marketing, innovation, and entrepreneurship, as well as various types of "on-the-job" training in an attempt to educate engineers who can help companies, countries, and continents compete successfully in the global marketplace.

A second response has been a professional or academic approach by which educators have tried to meet the challenges facing engineering in the contemporary world in a more traditional "scientific" manner. In relation to curricular construction, courses and even entire programs have been developed in new specialty areas such as sustainability science and technology, nanoscience and nanotechnology, industrial, urban, and even eco-design. In this response strategy, the ambition has primarily been to educate engineers who can be new kinds of professional experts while upholding a more traditional engineering identity. As a result, among different universities, as well as within many of the same ones, there is an ongoing tension or competition between the practical, market-oriented approaches and the scientific, academic-oriented approaches, which makes it difficult for students to receive a well-rounded and comprehensive education.

In this chapter, I will argue for the need for a third strategy that seeks to foster what I have come to call a "hybrid imagination" (Jamison et al. 2011). A hybrid imagination can be defined in this regard as the combination of a scientific-technical problem-solving competence with an understanding of the problems that need to be solved. It is a mixing of scientific knowledge and technical skills with what might be termed cultural empathy, that is, an interest in reflecting on the cultural implications of science and technology in general and one's own contribution as a scientist or engineer, in particular. It can be thought of as an attitude of humility or modesty, as opposed to arrogance and hubris, in regard to scientific and technological development, and, for that matter, to any kind of human activity. A hybrid imagination involves recognizing the limits to what we as a species and as individuals can do, both the physical limits and constraints imposed by "reality" as well as those due to our own individual limits of capabilities and knowledge.

A Paradigm Shift

In the course of industrialization in the nineteenth century and coalescing in the mid-twentieth century into what Stephen Cotgrove (1982) termed the dominant developmental paradigm, the theory and practice of "development" for a century and a half was generally characterized in material terms, as the promotion of economic growth and scientific-technological progress. Across the political spectrum, from conservatism to liberalism to social democracy, for both communists and capitalists, imperialists and anti-imperialists, the pursuit of material, "science-based" progress and economic growth served as a unifying goal for the development of human beings and the societies in which they live.

There were differences of opinion, to be sure, as to how economic growth and science and technology-based material progress could best be achieved, not least in regard to the role of the state and of government planning and policy. In most of the western European countries, as well as in the communist countries of Eastern Europe and the so-called developing countries of the Global South, the state was seen as a central actor, and economic growth was seen as a collective responsibility to be governed by a national state. In the United States, on the other hand, as well as in a number of countries most dominated by the United States ideologically and politically, the state's role was seen to be more limited. Economic growth was considered most effectively managed if it was left to so-called market forces; only those areas of development and engineering that were directly related to defense and to the military industries should be governed by a national or supranational state.

But in spite of these differences, there was until well into the 1960s an overarching discursive consensus, and practical convergence, throughout the world concerning the central importance of the pursuit of economic growth and scientific and technological progress for all of us, not least engineers.

The idea of sustainable development emerged out of the public debates of the late 1950s and 1960s, which challenged, from different perspectives, the pursuit of economic growth and material progress as the primary goals and priorities of human development (Jamison and Eyerman 1994). There were several forms in which this questioning took place. Most fundamentally perhaps, there was a moral or spiritual debate that was voiced by such people as Martin Luther King in the United States and Jacques Ellul in France and was accompanied by a resurgence of interest throughout the world in the Asian religious traditions of Buddhism, Taoism, and Islam.

What King termed the "poverty of the spirit" was part of a more general concern with the violations of human or civil rights that was so widespread in the technological society bemoaned by Ellul in his influential book, *La Technique*, from 1954, which was translated into English in the 1960s as *The Technological Society* (1964). The development of science and technology in pursuit of material progress had turned citizens into consumers, and, as a result, many contended that there was a need to bring a new kind of ethical or humanitarian concern into the making of science and technology (cf. Mitcham and Muñoz 2010).

As King put it, in his acceptance speech when he was awarded the Nobel Peace Prize in 1964:

> There is a sort of poverty of the spirit which stands in glaring contrast to our scientific and technological abundance. The richer we have become materially, the poorer we have become morally and spiritually…. Every man lives in two realms, the internal and the external. The internal is that realm of spiritual ends expressed in art, literature, morals, and religion. The external is that complex of devices, techniques, mechanisms, and instrumentalities by means of which we live. Our problem today is that we have allowed the internal to become lost in the external. We have allowed the means by which we live to outdistance the ends for which we live.

Another kind of debate concerned the impact that scientific and technological development was having on nature or what came to be referred to in the 1960s as the natural environment. While conservationists had been discussing the consequences that science- and technology-based economic growth was having on plants and animals, it would be Rachel Carson's book, *Silent Spring*, published in 1962, with its detailed exposé of the health and environmental implications of one particular widely used chemical in agriculture, the insecticide DDT, that would bring the environmental cause to public attention. It would also usher in a more activist and radical approach to environmental politics than had been characteristic of the older conservation societies which had been established in the late nineteenth and early twentieth centuries and tended to be located on the conservative side of the political spectrum.

What Carson and other environmentalists argued was that a full-fledged crisis was in the offing if science and technology were not changed into more environmentally friendly or ecological directions (Commoner 1971). Many of the new kinds of science-based products that had been produced in the immediate postwar era, especially the synthetic chemicals that were used in agriculture and food production and many health and household products as well, could not be broken down and recycled in nature as could the products they replaced and thus served to destroy the natural environment, as well as affecting human health.

There also emerged in the 1960s a more general questioning of the ways in which the broader society had been affected by the overarching concern with material progress and economic growth. The increasingly visible and horrific uses of science and technology in the war in Vietnam as well as the more general lack of a broader social responsibility in the ways that students were being educated brought on a wave of student revolts in the second half of the 1960s. Humanist scholars and philosophers, such as Hannah Arendt and Herbert Marcuse, who had fled from Nazism, saw in the scientific and technological pursuit of progress a new form of authoritarianism and wrote influential books about what Arendt called the "human condition" and what Marcuse called "technological rationality" and one-dimensional thought (Arendt 1958; Marcuse 1964).

As science and technology had become ever more integrated into the economy, and the state gap had emerged, not least in education, between what the British chemist-turned-novelist C.P. Snow termed the "two cultures" in a famous lecture in 1959. Snow's argument, which was echoed by many others throughout the world in the course of the 1960s was that both in education as well in the broader culture, scientists and engineers, on the one side, and humanists and writers, on the other, had come to form separate cultural identities in the modern world. Education and communication both in the professional and popular media had become polarized and overly specialized, and there was a need for both sides to know more about what the other was doing.

Reforming Engineering Education

One outcome of the debates of the 1960s was the emergence of teaching and research programs in science, technology, and society (STS) at universities throughout the world, to a large extent, to try to bridge the "two cultures" gap. The idea was to offer instruction about the social and cultural contexts of science and technology, as well as to provide meeting places for natural scientists, engineers, social scientists, and humanists for discussion seminars and workshops and eventually for carrying out research projects together. The field of STS, at least at the beginning, was part of a more general interest within universities to foster interdisciplinary studies.

A number of new universities were also created, often based on "student-centered" approaches to education that tried to transform the critical energy of the student revolts into more constructive directions. In Denmark, the new universities in Roskilde (1972) and Aalborg (1974) have ever since combined what has been called problem- and project-based learning, as opposed to the more traditional "book learning" that characterized the older universities. When applied to science and engineering, problem-based learning proved to be particularly effective as a way to connect university scientists, engineers, and their students more closely to the problems in the broader society and to help cultivate the sorts of communicative, managerial, and design skills that scientists and engineers would need if they were to be able to carry out their research and development work in a socially responsible manner.

In the course of the 1970s, there were also a number of centers set up outside the universities for appropriate, alternative, small-scale, and/or intermediate technologies, putting into practice the ideas that were propagated in such books as *Small is Beautiful* by E. F. Schumacher, an economist who had worked on development projects in India as well as for the British Coal Board, and *Tools for Conviviality*, by Ivan Illich. In the United States, a group of scientists and engineers left MIT to set up a "New Alchemy Institute" on Cape Cod, and for several years, they held courses and developed research projects combining organic agriculture, renewable energy, and other "ecological technologies." In the general spirit of "liberation" that filled the air at the time, many scientists and engineers throughout the world, but perhaps especially in the so-called third world or what is today called the Global South, sought to find ways to connect their scientific knowledge and technological skills to basic human needs. This was the expression used in many United Nations agencies in their activities and programs, as well as at the UN Conference on Science, Technology, and Development that was held in 1979 as part of the efforts on the part of developing countries to establish a "new international economic order" (Jamison 1994).

What I have previously termed the "cognitive praxis" of the environmental movements was based on a philosophy or cosmology of systemic holism derived from systems theory, cybernetics, and ecology (Jamison 1996). In the early 1970s, this new ecological worldview or paradigm was popularized in such books as Barry Commoner's *The Closing Circle* and in the book produced for the UN Conference on the Human Environment held in Stockholm in 1972, *Only One Earth* by Barbara Ward and René Dubos, as well as in *A Blueprint for Survival,* which launched the journal *The Ecologist*, and the extremely influential *Limits to Growth* that was produced by a group of experts reporting to the Club of Rome in 1972. Barry Commoner's four laws of ecology – "everything is connected to everything else," "everything must go somewhere," "nature knows best," and "there is no such thing as a free lunch" – provided a set of cosmological or worldview assumptions for the environmental movements that, in the course of the 1970s, became significant political actors in several northwestern European countries as well as in North America. In political campaigns directed against various kinds of air and water pollution, chemicals in food and agriculture, and especially against the development of nuclear energy, environmental movement organizations, together with students and teachers at universities, began to turn scientific knowledge and technological development green.

In the environmental movements of the 1970s, this ecological philosophy or worldview was combined with a practical or technical experimentation in new movement settings that included a wide range of production collectives and alternative communities. At these sites, environmental and energy activists could learn about "environmentally friendly" ways to produce energy, food, and the other necessities of life that were based on an ecological worldview. Activists and academics joined together to build solar energy panels and wind energy plants, grow organic food, and try to live more ecologically (Boyle and Harper 1976). In the Netherlands, "science shops" were established at several universities to provide meeting places between the academic world and the broader society, and in many other countries, the environmental movements fostered other forms of what the sociologist Alan Irwin later termed "citizen science" (Irwin 1995).

A kind of "grassroots" engineering emerged in many parts of the world, particularly in relation to the antinuclear energy movements. In Denmark, scientists and engineers created a national Organization for Renewable Energy (or OVE, *Organisation for vedvarende energi*) that helped people throughout the country to learn how to build their own wind energy plants and solar panels (Jamison 1978). OVE arranged courses at older as well as newly established folk high schools, and its members created centers for renewable energy such as the Nordic center in Thisted, which is still in operation. In 1978, the world's then largest wind energy power plant was constructed by students at the Tvind folk high schools on the Danish west coast, not far from where VESTAS is now based. Mobilizing a Danish tradition – Poul la Cour, a folk high school physics teacher in the nineteenth century, had been one of the first in the world to experiment systematically with wind-power-generated electricity production – the Organization for Renewable Energy has continued to foster "grassroots innovation" ever since. By the late 1970s, the movement had spawned a number of companies, one of which, VESTAS, is now the leading wind turbine producer in the world and one of Denmark's largest companies.

In the 1980s, as the political climate in North America and northwestern Europe turned to the right, environmental politics changed character, and the making of green engineering changed as well. This right turn in politics represented a mobilization of conservative traditions, or – as they are often referred to in the United States – neoconservative values. Traditional religious and nationalist concerns were fundamental to these neoconservative movements, which emerged, at least in part, as a kind of organized opposition, or "backlash," to the environmental and women's movements of the 1970s and the kind of knowledge they had embodied and articulated (Helvarg 1988; Rowell 1996).

At the same time, in the early 1980s, the environmental movement itself fragmented into a number of different organizations and institutions, both in terms of politics and knowledge-making. Green parties were formed in many countries and professional activist organizations, such as Greenpeace, grew in significance, while the broad-based, or grassroots, organizations that had led the campaigns against nuclear energy in the 1970s tended to lose members. Within universities and new environmental "think tanks" such as the World Resources Institute and the Wuppertal Institute, environmental and energy experts started to make more specialized kinds of knowledge in relation to renewable energy, organic agriculture, and eventually to climate change and other "global" issues as well (Jamison 1996).

As such, more professional and established forms of knowledge-making started to replace the kinds of appropriate or alternative forms of citizen science and grassroots engineering that had been so prominent in the 1970s. Many of those who had been active in the environmental and energy movements in the 1970s left the movement "space" behind to make careers in universities as well as in the wider worlds of government, media, and business.

In 1987, the report, *Our Common Future*, was published by the World Commission on Environment and Development, headed by the former Norwegian prime minister, Gro Harlem Brundtland, and with representatives from government, business, academia, as well as from environmental think tanks and so-called nongovernmental organizations. With its call for "sustainable development" – by which was meant a kind of socioeconomic development that took into account the needs of future generations for natural resources – the report signaled the coming of a new international political doctrine in which environmental concern was to be included into all other areas of socioeconomic and cultural development. But the quest for sustainable development would come to be a contentious process, with different conceptual interpretations and implementation strategies vying for support and influence in the years to come.

The Commercial or Market-Oriented Response

Following the fall of the Soviet empire, and the so-called Earth Summit in Rio de Janeiro in 1992 (the UN Conference on Environment and Development), where the ideas of the Brundtland report about sustainable development were translated into the Agenda 21 document, new approaches to greening science and engineering proliferated in the 1990s. Particularly prominent were the efforts to encourage more practical, market-oriented solutions to environmental problems. The general approach can be thought of as an incorporation of environmental concern into the world of business. In the course of the 1990s, there emerged a range of activities in such areas as environmental management, cleaner technology, eco-efficiency, environmental impact assessment, industrial and urban ecology, and green product development, which are explicitly commercial: this was engineering knowledge that was meant to be sold on the market.

These forms of knowledge-making became especially important in several European countries, where social-democratic governments, often with the support of green parties, pursued policies of "ecological modernization" as did the Clinton-Gore administration in the United States. In Germany, Great Britain, Denmark, Sweden, and the Netherlands, as well as at the European Commission, ecological modernization sought to combine environmental concern with economic growth. As climate change became a more integral part of environmental politics in the 1990s, it was the market-oriented approaches that tended to dominate the international deliberations, both in Kyoto, as well as within intergovernmental administrative and scientific advisory bodies, such as the Intergovernmental Panel on Climate Change (IPCC).

The rise of market-oriented environmentalism or green business was shaped by the broader neoliberal movement, which has provided the dominant story line of the past two decades, both in regard to science and technology in general, and environmental science and technology, in particular (Hoffman 2001). Much of the knowledge-making activity within green business tends to be organized in commercial networks, with university scientists and engineers working together with companies on specific projects. There are also a number of "movement intellectuals" in the commercial media as well as in private consulting companies who serve to articulate the underlying importance of meeting the sustainability challenge in commercial terms (Jamison 2010). The "cognitive praxis" of green business exemplifies the dominant approaches of academic capitalism in the promotion of commercially oriented technological innovation and green product development.

The cosmology of green business is based on a belief in a convergence between economic growth and environmental protection, and depending on the context, it has been termed ecological modernization, eco-efficiency, corporate sustainability, or green growth. In the words of Maarten Hajer, what was central to the political discourse of ecological modernization in the 1990s was "the fundamental assumption that economic growth and the resolution of the ecological problems, can in principle, be reconciled. Hence, although some supporters may individually start from moral premises, ecological modernization basically follows a utilitarian logic: at the core of ecological modernization is the idea that pollution prevention pays" (Hajer 1995, p. 27). In the course of the past 15 years, particularly in China and other Asian countries, this fundamental assumption is central to major national programs in "green growth."

In relation to engineering education, it has led to a wide range of courses and educational programs in such topics as sustainable innovation and environmental management, as well as more specialized areas, such as sustainable energy planning, mobility management, and sustainable design. Many of these initiatives, such as those at my own university, in Aalborg Denmark, are built on collaborative efforts between business firms and engineering teachers and involve internships and other forms of on-the-job training in companies as part of the educational program.

The Professional or Academic-Oriented Response

Already in the 1980s, Aant Elzinga noted how established epistemic criteria, that is, the ways in which truth claims are justified by scientists and engineers, were in a state of flux, as scientists and engineers increasingly found themselves in a condition of what he termed "epistemic drift":

> …the process whereby, under strong relevance pressure, researchers become more concerned with external legitimation *vis-à-vis* policy bureaucracies and funding agencies than with internal legitimation via the process of peer review. This may be seen as a process of erosion of the traditional system of reputational control.
>
> (Elzinga 1985, p. 207).

Since then the traditional norms or values of scientists and engineers have been increasingly challenged by the transition to new ways or modes of doing research. To borrow a term from the French sociologist Pierre Bourdieu (2004, p. 65), the "habitus" of science and engineering, a way of life based in distinct academic disciplines and professional identities, which provided what Bourdieu characterized as a "collective capital of specialized methods and concepts," has been invaded by other forms of organization and ways of working.

Not all scientists and engineers have accepted the new world of academic capitalism. A good many of them have reacted quite critically to the changing contextual conditions and have sought to reaffirm a more academic or professional approach to science and engineering as a way to respond to the challenges. And while it certainly is valuable to uphold the importance of academic quality and professional standards, such responses tend to become anachronistic in that they all too often merely reassert the traditional norms of academic life and professional behavior, without recognizing that those norms and values have, to a large extent, become outmoded (Christensen and Ernø-Kjølhede 2006).

As part of this strategy, it has become popular to refer to the norms of science, which were influentially formulated in the 1940s by the American sociologist Robert Merton (1942). These have long been seen by many natural and social scientists, as well as engineers and large segments of the general public, as core values in science and engineering. The norms of communalism, universalism, disinterestedness, and, not least, organized skepticism continue to be seen as defining features of science, even though the practice of science has fundamentally changed since Merton characterized them. But the Mertonian norms continue to be propagated and considered to be part of the identities of scientists and engineers, particularly in relation to contentious issues such as sustainable development and climate change, where, among others, the Danish political scientist Bjørn Lomborg has been particularly successful in promoting the value of organized skepticism (Jamison 2004).

In relation to engineering education, the reassertion of professional values and norms has led to an educational strategy of academicization by which the various challenges facing engineering tend to be translated into new scientific or disciplinary programs for training in specialized areas of expertise. Such fields as ecological economics, sustainability science, and the various subfields of climate science – atmospheric chemistry, oceanography and hydrology, climate modeling, etc. – have spawned and become subjects of educational programs either as stand-alone disciplines on their own or as sustainability "minors" or electives that are added onto traditional science and engineering programs. What is stressed in these programs is the scientific credentials of the teachers and the adherence to the traditional academic values and professional norms. Particularly in relation to climate change, this skepticism has been a part of the political debate and, not least, criticism of the policy proposals of the "transdisciplinary" and highly networked scientists and engineers who have called for major expenditures on renewable energy systems and other green business ventures.

A Hybrid Imagination

In order to meet the challenges facing science and engineering in the world today, it is my contention that it is not sufficient to reaffirm a traditional faith in reason and truth and reassert the importance of a largely outmoded form of engineering professionalism. There is instead a need to foster a hybrid imagination, connecting science, technology, and society in new ways, by combining scientific knowledge and technical skills with cultural understanding as a part of what has been called the global justice movement.

Since the late 1990s, a new kind of political activism, often involving forms of civil disobedience and direct action, has emerged in relation to environmental issues and, most recently climate change, as a part of what has been characterized as a broader movement for global justice (Jamison 2010). In addition to political protests, which became most visible, in relation to sustainability issues, in the streets of Copenhagen at the end of 2009 during the COP15, there are a number of primarily local organizations in both the Global North and Global South that carry out a range of more constructive activities in relation to such areas as renewable energy, ecological housing and design, and organic agriculture. In recent years, there have been attempts to arrange gatherings, where the different component parts of the global justice movement can meet and discuss their concerns and exchange their experiences. These various "social forums," as they have come to be called, have taken place both at an international level (at world social forums, that have been held each year since 2000) as well as at more regional, national, and local levels, particularly in Europe.

There are a growing, but still relatively small, number of cases of collaboration between academics and activists in universities and local communities in trying to deal with climate change and other environmental problems in just or equitable ways (Hess 2007; Worldwatch Institute 2010). New forms of community-based innovation and knowledge-making can be identified in local food movements around the world, as well as in a range of not-for-profit engineering projects in such areas as sustainable transport, renewable energy, and low-cost, environmentally friendly housing. Such projects as the Alley Flat Initiative at the University of Texas in which students and teachers from the School of Architecture have designed low-cost, climate-smart housing in East Austin in cooperation with local housing suppliers and neighborhood groups show what can be done (Jamison 2009).

The Alley Flat Initiative emerged as part of a larger project on sustainable development, directed by architecture and planning professor Steven Moore. Moore had combined with his colleagues a number of course in different departments into a sustainability portfolio that students can acquire along with their degrees, a sort of green credential. He also established a design studio for masters students in architecture and planning taught not only by Moore but also by Louise Harpman and a visiting professor, Sergio Palleroni, who had previously carried out community-oriented architectural projects with students at the University of Washington. Looking for a specific focus for the studio, the students spent time in East Austin, the area of the city that in the early twentieth century had been segregated through the provisioning of infrastructure as an African-American, Latino, and industrial area. Like many such areas in many American cities, east Austin became threatened by so-called gentrification when Blacks and Latinos cleaned up industrial brownfields over six or seven decades, making the area attractive to more wealthy whites.

The motivation behind the initiative was to find a way to learn architecture by doing something useful for the community, and after looking through maps, and reading about the history of the area, the students came up with the idea of designing climate-smart alley flats or second houses along the alleys – what used to be called "granny flats" because they were where grandparents lived – that could help the residents pay their escalating property taxes and fight off gentrification and also contribute to the transition to a low-carbon society. As described on the initiative's website:

> The initial goal of the project was to build two prototype alley flats – one for each of two families in East Austin – that would showcase both the innovative design and environmental sustainability features of the alley flat designs. These prototypes were built to demonstrate how sustainable housing can support growing communities by being affordable and adaptable. The first of these prototypes celebrated its house warming with the community in June of 2008 and the second prototype was completed in August of 2009. The long-term objective of the Alley Flat Initiative is to create an adaptive and self-perpetuating delivery system for sustainable and affordable housing in Austin. The "delivery system" would include not only efficient housing designs constructed with sustainable technologies, but also innovative methods of financing and home ownership that benefit all neighborhoods in Austin.
>
> (AFI 2011)

Unfortunately, however, such activities fall well outside of the mainstream and remain quite marginal at universities throughout the world, although, in recent years, several universities in the United States have established programs in engineering for sustainable community development (Lucena et al. 2010). In some of these programs, there is a similar kind of institutional outreach that was so characteristic of the "movement" activities that took place in the 1970s, but most of them have a difficult time establishing themselves at universities. The increasing encroachment of a commercial and entrepreneurial value system at universities makes it difficult for concerns with social justice and cultural change to be given the attention they deserve in science and engineering education.

Conclusions

As such, the greening of engineering and engineering education can be seen as an ongoing process of contention between three very different approaches or strategies. The dominant approach can be considered a part of what has been termed the new "mode" of knowledge production or "mode 2," in which the borders between the academic and business worlds are increasingly transgressed. On the other hand, there is an academic or professional approach to engineering and engineering education that is based on a more traditional conception of science-based, expert knowledge. In this approach, education tends to be carried out in accordance with the more traditional scientific disciplines and engineering fields.

A third approach that explicitly connects the quest for sustainable development to concerns of global justice and fairness is comparatively weak at the present time. Since the challenges facing engineering in the world today, and not least the sustainability challenge is so all-encompassing and multifaceted, I have suggested that it will be necessary in this emerging third approach to engineering education to foster a "hybrid imagination," mixing natural and social, local and global, academic and activist forms of teaching and learning in new combinations.

At a time when the global economy is in a state of crisis and the need for sustainable development is growing ever more urgent, much will depend on the ways in which science and engineering education and universities more generally respond to the challenges they face. All too many efforts around the world today in regard to greening or sustainable development are more rhetorical than real, more concerned with branding and image-building than with substantive integration of contextual knowledge into educational programs. There must be more room or space at universities for students and teachers to undertake "not-for-profit," community-oriented activities in relation to their education. In a world in which universities have become ever more subjected to "market forces" in order to contribute to their "global competitiveness," cross-disciplinary and cross-cultural education and knowledge-making is, to put it mildly, not particularly encouraged, well supported, or understood. If scientists and engineers are to meet the challenges that they face in a meaningful way, however, it will be crucially important in the years to come to see to it that our universities can help to foster hybrid imaginations, perhaps especially among science and engineering students.

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Chapter 2
From a Micro–Macro Framework to a Micro–Meso–Macro Framework

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Abstract At the beginning of the twenty-first century, the philosophy of engineering is becoming its own distinct branch of philosophy. The growing importance of philosophy of engineering cannot be overemphasized, since it has raised or will raise considerable and fundamental issues that challenge traditional ontology, methodology, and epistemology. Engineering is extremely complicated. Without initiating and advocating a new conceptual framework or paradigm, including a number of new categories, neither philosophers nor engineers could comprehend or demonstrate the essential characteristics of engineering. In particular, some social scientists pay significant attention to the relationship between micro (at the level of individuals) and macro (at the level of institutions or the social whole) issues, and as a result, a variety of micro–macro frameworks have advanced. There are four approaches for scientists to investigate social phenomena: micro-theory-based approach, macro-theory-based approach, micro–macro approach, and micro–meso–macro approach. As for engineering phenomena, scholars should focus on engineering facts, engineering acts, and engineering results, which comprise the three layers. A great number of perspectives contribute to a more complete and deeper understanding of engineering practice as a kind of multiple social construction assemblage. Engineering as a tangible architecture of social reality should be explained as a kind of multiple construction undertaken at micro, meso, and macro levels. The traditional micro–macro framework is obsolete. As such, it is time to establish a new kind of micro–meso–macro framework.

Keywords Engineering • Philosophy of engineering • Micro–macro • Micro–meso–macro • Social reality • Social construction • Engineering reality

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Introduction

At the beginning of the twenty-first century, philosophy of engineering is becoming its own distinct branch of philosophy that is considered as parallel to philosophy of science and philosophy of technology. Tracing the history of philosophy of technology, Carl Mitcham finds that four authors, Ernst Kapp (1808–1896), Peter K. Engelmeier (1855 to ca. 1941), Eberhard Zschimmer (1873–1941), and Friedrich Dessauer (1881–1963), employed the term "philosophy of technology" as the title of a book at the beginning of philosophy of technology (Mitcham 1994, pp. 20–33). Ernst Kapp, the first author, published Grundlinien einer Philosophie der Technik (*Grounds for a Philosophy of Technique*) in 1877, and Dessauer published Philosophie der Technik (*Philosophy of Technique*) in 1927. The philosophy of technology mainly arose in Europe, particularly in Germany, as demonstrated by the fact that Ernst Kapp, Eberhard Zschimmer, and Friedrich Dessauer are German philosophers or engineers, and Peter K. Engelmeier, a Russian engineer, who having lived in Germany for many years, first used the phrase "philosophy of technology" in a German newspaper in 1894 (Mitcham 1994).

In contrast to the situation that philosophy of technology developed slowly during the first 50 years, philosophy of engineering developed quite rapidly during the last 10 years. Supporting this contention is that at the beginning of the twenty-first century, four books entitled philosophy of engineering or its synonym, namely, Gongcheng Zhexue Daolun (*An Introduction to Philosophy of Engineering*, by Li Bocong 2002), *Engineering Philosophy* (by Louis L. Bucciarelli 2003), Gongcheng Zhexue (*Philosophy of Engineering*, by Yin Ruiyu et al. 2007), and Philosophy in Engineering (by Steen H. Christensen et al. 2007), were published during a 5-year span, rather than the 50 years it took for philosophy of technology to become as established. Another important point is that the authors of the four books are Chinese, American, Danish, Dutch, French, and so on, rather than scholars from only one or two European countries, which is quite different from the situation for the first 50 years of writings on the philosophy of technology. Therefore, it seems clear that philosophy of engineering rises and emerges simultaneously in China, USA, and Europe rather than only in one continent.

The conditions in the first decade of the twenty-first century for philosophy of engineering were quite different from those in the first 50 years of philosophy of technology. Furthermore, it is utterly different from the environment about 20 years ago when philosophy of engineering was at the embryonic stage of its development. In the early 1990s, Steven L. Goldman wrote two excellent articles on philosophy of engineering (Goldman 1990, 1991). Here, he said that philosophy of science at that time was a fully accepted and highly respected branch of philosophy, while philosophy of engineering still carried as much professional distinction as philosophy of parapsychology.

However, Goldman took an optimistic view of the future for philosophy of engineering. He held that philosophy of engineering should be the paradigm for philosophy of science, rather than the reverse (Goldman 1990, p. 140). In the current academic field, due to the fact that philosophy of engineering is still a fledgling subdiscipline, engineers and philosophers who study in the domain of philosophy of engineering often have to use paradigmatic and categorical approaches from philosophy of science. For instance, to promote the development of philosophy of engineering, following the example of philosophy of science and other subdisciplines of philosophy, scholars raised the issue of context in engineering which appears parallel to the issue of context in science (Christensen et al. 2009). Nevertheless, just as the Goldman's claim quoted above, it is possible that some new issues, even a new paradigm, will be raised in the field of philosophy of engineering in the future.

Goldman argues,

> In the absence of an institutionalized and fertile science, engineers generate their own theoretical knowledge in the course of solving their problems. They have been doing so for millennia, and continue to do so today. Furthermore, as Layton has shown, even where engineers did explicitly borrow from science, in thermodynamics and in electrical theory, for example, they had to rethink the abstract scientific knowledge and reformulate it as concrete engineering knowledge. If we then add to this the knowledge, the conclusion must be that science is not either chronologically or logically prior to engineering.
>
> (Goldman 1990, p. 143)

Although philosophy of science predates philosophy of engineering, it does not follow that categories and frameworks of philosophy of science are logically antecedents to those of philosophy of engineering. On the contrary, it is possible that some new categories and frameworks are raised or discussed in the field of philosophy of engineering more fundamental than those arising from the philosophy of science. Since philosophy of engineering is raising or will raise some fundamental issues which challenge traditional ontology, methodology, and epistemology, I believe that Goldman's forecast on the future of philosophy of engineering will come true.

Engineering is extremely complicated phenomena. Without initiating and advocating a new conceptual framework or paradigm, including a number of new categories, neither philosophers nor engineers could comprehend or demonstrate the essential characteristics of engineering. In this chapter, I will devote a brief discussion to a new topic that concerns a micro–meso–macro framework or, you might say, a micro–meso–macro theory. Although the micro–meso–macro framework concerns almost all aspects of engineering, such as philosophical, economic, sociological, managerial, ethical, institutional, and psychological issues, the focus of this chapter will be mainly upon philosophical aspects.

Although the three different levels, namely, micro level (typically concerning the level of individual actors within organizations), meso level (intermediate level of organizations), and macro level (level of social institutions), can be easily found in engineering practice and engineering studies, a number of scholars have concentrated mainly on the micro level or macro level for a long time. Only recently have scholars paid attention to the meso level. Most important of all, there have been few scholars who have addressed the integration of the micro level and the macro level or the integration of the three levels. Therefore, a theoretical and methodological shift from a micro or macro theory to a micro–meso–macro theory takes place in some disciplines but is not a marked movement. Should we establish a micro–meso–macro framework or a micro–meso–macro theory in philosophy of engineering? From my point of view, the answer is definitively yes.

Micro Frameworks/Macro Frameworks in Some Disciplines

Some scholars pay great attention to micro and macro issues in ethics, sociology, economics, and philosophy. Thus, a variety of micro frameworks or macro frameworks are put forward. Due to variety of micro, macro, and micro–macro frameworks, the topic of frameworks is beset with difficulties. When the topic is discussed, many scholars find that they have gone into a jungle of concepts. In the first place, different scholars usually have various opinions on a conception. In this chapter, the differences among scholars cannot be analyzed in detail. Another difficulty lies in the situation in which scholars from different academic fields illustrate the same topic from various perspectives. Last but not least, different scholars often used different words or terms for an underlying concept, even within the same academic field.

The fact has to be noted that there is no unified micro–macro framework in the domains of different disciplines. That is to say, a micro or macro framework of a discipline may be quite different from one discipline to another. For example, a framework established in ethics is quite different from another in economics or in sociology. The discussion on the issue of frameworks has to be simplified to some extent. In this chapter, the topic will only be analyzed in terms of the main trend or new trends, and it is unavoidable that some details are overlooked.

Some ethicists hold that a kind of micro framework is dominant in the field of morality. According to the traditional theory, moral issues, such as responsibility, honesty, friendship, and duty, are always attributed to individual characteristics that hint that a micro framework has been regarded as the sole one by the majority of ethicists. Only recently, a few ethicists have begun to pay attention to some macro issues. For example, Mike W. Martin and Roland Schinzinger write,

> Micro issues concern the decisions made by individuals and companies. Macro issues concern more global issues, such as the directions in technological development, the laws that should or should not be passed, and the collective responsibilities of groups such as engineering professional societies and consumer groups. Both micro and macro issues are important in engineering ethics, and often they are interwoven.
>
> (Martin and Schinzinger 2005, p. 6)

Although a few scholars in ethics raised and began to advocate a micro–macro framework, it seems that a great number of ethicists have been advocating a mere micro framework and neglecting the micro–macro framework, not to mention a micro–meso–macro framework. Different from the field of ethics in which a micro framework generally prevails, both a micro and a macro framework prevail in the field of sociology. Some sociologists advocate the former and others advocate the latter. As a result, two subdisciplines of sociology, namely, macro-sociology and micro-sociology, came into existence. Generally speaking, micro-sociology and macro-sociology means that micro and macro frameworks exist in sociology.

Similar to sociology, economics is also divided into two subdisciplines, microeconomics and macroeconomics. As to the definitions of microeconomics and macroeconomics, the majority of economists hold a unified opinion. Wikipedia provides the following definition of microeconomics:

> Microeconomics (from Greek prefix micro- meaning "small" + "economics") is a branch of economics that studies the behavior of how the individual modern household and firms make decisions to allocate limited resources. Typically, it applies to markets where goods or services are being bought and sold. Microeconomics examines how these decisions and behaviours affect the supply and demand for goods and services, which determines prices, and how prices, in turn, determine the quantity supplied and quantity demanded of goods and services.

Although there are micro and macro subdisciplines, both in the field of economics and in the field of sociology, the situation in which two subdisciplines developed in economics is in sharp contrast to what happened in sociology. For example, in the field of economics, a variety of microeconomics textbooks and macroeconomics textbooks have been published. On the contrary, in the field of sociology, few micro-sociology and macro-sociology textbooks can be found. On the basis of this sharp contrast, it would seem to be a logical conclusion that microeconomics and macroeconomics are two true subdisciplines of economics while micro-sociology and macro-sociology are only two important issues or approaches in sociology.

Although ethicists, economists, and sociologists have built their own micro frameworks or micro theories, an important fact must be noted that an economic micro framework is not comparable to the ethical micro framework or the sociological one. Indeed, the economic micro framework differs from both of them to a large extent. It should be noted that a micro framework in economics often distinguishes itself from a micro framework in other discipline such as ethics. For example, both an individual and a firm are regarded as a micro unit in economics, while only individuals are regarded as an ethical micro unit. A firm or an enterprise is not regarded as a micro unit in ethics by some scholars. From the economic point of view, a micro subject in the economic field means an economic "individual agent," which could represent an entire company or household. However, a micro subject in the sociological or moral sense means respectively a sociological individual or an ethical individual. Generally speaking, an economic "actor" acts differently from a sociological individual and an ethical individual. The three may act with distinctly different principles.

This chapter will not completely analyze the relationships and distinctions among micro frameworks in different disciplines such as economics, sociology, and ethics. More attention is given to the relationship between a micro framework and a macro framework.

From a Micro–Macro Split Toward Micro–Macro Integration

A heated debate on a micro theory and a macro theory arose not only in sociology but also in economics. Some scholars hold that the micro–macro split and the micro–macro debate in sociology lasted for more than a century and a half (Alexander

1988a, p. 260). In the fields of philosophy and economics, individualism and holism are two opposite kinds of fundamental theories. The former means a kind of a micro framework and the latter means a kind of a macro framework. Due to the limited space of this chapter, a subtle difference between micro/macro and individualism/holism in social science will be neglected, and for purposes here, individualism/holism is regarded as a synonym of micro/macro.

Now, I turn my attention to the topics of individualism and holism. It seems that some economists, to avoid discussing ontological issues, prudently employ the terms "methodological individualism" and "methodological holism" which are substitutes for ontological individualism and ontological holism. Of course, this is not to suggest that all economists want to avoid discussing ontological issues. In contrast to many economists who prefer the terms methodological individualism and methodological holism to the terms ontological individualism and ontological holism (Rutherford 1994, pp. 27–50), some philosophers prefer the terms ontological individualism and ontological holism to the methodological terms (Gilbert 1989, pp. 428–430). Although the term "methodological individualism" is literally different from the term "ontological individualism," the meaning of methodological individualism is almost identical with that of ontological individualism. The relationship between methodological holism and methodological individualism is almost identical as that between ontological holism and ontological individualism. As a matter of fact, methodological individualism cannot be separated from ontological individualism, and methodological holism also cannot be separated from ontological holism. It is impossible to advocate individualism or holism merely in the field of methodology. Scholars who advocate individualism or holism have to inevitably discuss ontological issues as well as methodological issues. In fact, the majority of scholars, including economists, sociologists, and philosophers, expound individualism or holism both from methodological and ontological perspective. Malcolm Rutherford writes,

> Methodological holism (MH) is an approach associated with sociology and anthropology more often than economics. The holist approach can be summarized as follows:
>
> MH (i) The social whole is more than the sum of its parts,
>
> MH (ii) The social whole significantly influences and conditions the behaviour or functioning of its parts,
>
> MH (iii) The behaviour of individuals should be deduced from macro-scopic or social laws, purposes, or forces that are sui generis and that apply to the social system as a whole, and from the position (or function) of individuals within the whole.
>
> (Rutherford 1994, p. 28)

Similarly, methodological individualism (MI) can be summarized in three statements:

> MI (i) Only individuals have aims and interests,
>
> MI (ii) The social system, and changes to it, result from the action of individuals,
>
> MI (iii) All large scale sociological phenomena are ultimately to be explained in terms of theories that refer only to individuals, their dispositions, resources, and interrelations.
>
> (Rutherford 1994, pp. 31–32)

According to Rutherford's account, it is obvious that both individualism and holism concern not only epistemology but also ontology. Generally speaking, while economists who advocate mainstream economics stand for methodological individualism, economists who advocate heterodox economics stand against methodological individualism. It is said that Joseph Schumpeter invented the term "methodological individualism." However, from substantial perspective, methodological individualism has a longer history. Ludwig von Mises and Friedrich A. Hayek can be regarded as individualists, but some thinkers of the eighteenth and nineteenth centuries, for example, Jeremy Bentham and John Stuart Mill, can also be regarded as individualists (Hodgson 1988, pp. 55–56). Other scholars openly criticized individualism and supported holism. Therefore, a fierce debate on the subject of individualism and holism arose. In recent decades, new classical economists argue against holism, and some institutional economists argue against individualism (Hodgson 1988, p. 61).

The debate between individualism and holism has lasted for a long time in philosophy, economics, sociology, and ethics. The debate is sometimes heated and it is always difficult to understand the issues involved. The difficulties lie not only in the use of varied terms employed by scholars but also in the variety of contexts in which the debate is surrounded. The debate between individualism and holism illuminates the micro–macro split. While many sociologists, economists, and philosophers consider that individualism and holism are completely opposite, others consider that both of them can be integrated in some way. But, is it possible to integrate individualism with holism?

Admittedly, although individualism and holism are completely opposed to each other as kinds of fundamental theories, all individualists do not deny that there are collective events, while all holists do not deny that individuals are agents. Both scholars who advocate individualism and those who advocate holism try to a certain extent to establish a link between a micro theory and a macro theory. But that does not mean that they advocate an approach to integrate individualism and holism into one framework. Actually, the majority of individualists advocate a reductionist approach, and the majority of holists advocate a different one that can be named a holist or structural approach. As Rutherford says,

> Methodological individualism is usually associated with the reductionist claim that all theories of social science are reducible to theories of individual human action. Put another way, this means that the only allowable exogenous variables in a social science theory are natural and psychological givens. The emphasis is therefore on how individual action gives rise to institutions and institutional change. By contrast, holism is concerned with the social influences that bear on individual action. The individual is seen as socialized, as having internalized the norms and values of the society he inhabits. The holist focuses attention on how social 'forces' (institutions, social conventions, etc.) condition individual behaviour.
>
> (Rutherford 1994, pp. 27–28)

Although, inevitably, individualists talk about collective action and holists talk about individual action, the situation does not imply that individualists and holists involve in a common approach. It is obvious that an individualistic approach is quite different from a holistic one. The former is a kind of micro-based approach, and the latter is a kind of macro-based approach. That is to say, the former means a micro framework and the latter means a macro framework. Neither of them can be really regarded as a kind of integration between individualism and holism (collectivism). Other scholars, such as Jeffrey C. Alexander and Joseph Agassi, try to find their way out of the split of individualism and holism and advocate a kind of integration between a micro theory and a macro theory or individualism and holism (collectivism) in the strict sense of the term "integration." Integration between a micro theory and a macro theory has attracted many scholars' attention. As a result, a variety of micro–macro theories have been raised. Joseph Agassi as a philosopher proposed institutional individualism (Agassi 1975). The institutional individualism is not a kind of pure individualism, but a combination of individualism and holism. Recently, more and more economists try to combine individualism with holism. In the history of sociology, it is said that Max Weber was the first sociologist who tried to synthesize the micro side and macro side and Talcott Parsons was the second sociologist who carried out similar work (Alexander 1988a, pp. 271–281). The trend of the micro–macro link increased in the 1980s. Sociological theory was said to be at a turning point at that time. On criticizing one-sidedness of schools of micro theorizing and one-sidedness of schools of macro theorizing, Jeffrey C. Alexander analyzes the situation at that time:

> I will demonstrate that one-sidedness has created debilitating contradictions within both the micro and macro traditions. It has been in order to escape these difficulties, I will suggest, that a younger generation of sociological theorists has set out an agenda of an entirely different kind. Among this new generation of theorists there remain fundamental disagreements. There is one foundational principle, however, about which they agree. Neither micro nor macro theory is satisfactory. Action and structure must now be intertwined. Where even 10 years ago the air was filled with demands for radical and one-sided theoretical programs, in the contemporary period one can only hear urgent calls for theorizing of an entirely different sort. Throughout the centers of Western sociology—in Britain and France, in Germany and the United States—synthetic rather than polemical theorizing now is the order of the day.
>
> (Alexander 1988b, p. 77)

Alexander and some sociologists tried to push "the new theoretical movement" forward in order to cut out their own way as a "third way" in the debate. The "third way" apparently means a new one that is not only different from a micro path but also different from a macro path. The aim of the third way is to integrate a micro theory with a macro theory. It seems to some theorists that such a way, which means an approach from the micro–macro split toward micro–macro integration, would be a hopeful one.

More than two decades have drifted by since Alexander talked about the new theoretical movement in sociology. Contrary to the Alexander's optimistic expectation, "the new theoretical movement" gradually vanished. Now, a great number of theorists find that they still stand at a turning point or crossroads. Many scholars think that the question about the relationship between micro and macro theories is still not resolved. Although a substantial advance has been made in the linkage, conciliation, or integration of a micro framework and a macro framework, a great number of intricate and insoluble problems remain. There is a long way for sociologists to really go beyond the micro–macro split.

A Micro–Meso–Macro Framework: Beyond a Micro–Macro Framework

On hearing the call for the new theoretical movement, Göran Ahrne made a pointed remark on the movement:

> This seemingly unchallenged position of the movement may explain its rather bloodless and quiet appearance. There is a lack of vigour in the movement; it has a flavour of avant-garde and self-sufficiency at the same time. Although one has to agree with its general goal and aims one also has to fear the transformation of the movement into a mutual admiration society. There is a risk that the connection between micro- and macrotheory will have little to do with relations between the world and the everyday lives of ordinary people.
> (Ahrne 1990, pp. 4–5)

Ironically, just as Ahrne pointed out, Giddens who is said to be a representative of the new theoretical movement has criticized the idea of formulating theories in terms of micro and macro (Ahrne 1990, p. 7). To make a long story short, it seems to some scholars that the new theoretical movement approaches an end that not only the split between individualism and holism but also the integration between the two sides is unsatisfactory. This means that the effort to cut out a "third way" failed in some sense. Such being the case, is it possible for a "fourth way" to be discovered and cut out? In order to carve out a "fourth way," some scholars discerned "meso" being a new issue, a new level, or a new category in social sciences, including economics, sociology, ethics, and even philosophy.

In 1980s, few scholars distinguished a meso level from a micro level or a macro level. And for this reason, they could not establish a micro–meso–macro framework in academic fields. In 1990s, the situation was changing. A small number of scholars, such as K. E. Goodpaster, Georges Enderle (2002), and Ronald Jeurissen (1997), began to pay attention to the topic of a micro–meso–macro framework in the field of business ethics. However, the majority of ethicists, economists, sociologists, and philosophers neglected the micro–meso–macro framework for a long time.

A meso level is obviously essential in a micro–meso–macro theoretical system, and it has a deep and far-reaching influence on how the other two parts are considered. After specifying a meso level, a micro–meso–macro framework as a new framework was established, at least in principle. The number of scholars who advocated a micro–meso–macro framework could be counted on the fingers of one hand in 1980s and 1990s. In the first decade of the twenty-first century, the number of scholars who began to pay attention to the great vitality of a micro–meso–macro framework increased slightly in the academic fields. Particularly, some scholars who conduct research in the fields of business ethics and evolutionary economics directed their attention toward a micro–meso–macro framework. However, the majority of scholars continued to neglect the micro–meso–macro framework.

In 2004, Kurt Dopfer, John Foster, and Jason Potts published their excellent article "Micro-meso-macro" (Dopfer et al. 2004) in which a micro–meso–macro framework is expounded. In 2009, Tan Weidong published *Economic Ethics: A Beyond-Modernism perspective* (Tan 2009). Li Bocong (author of this chapter) gave a lecture in which a micro–meso–macro framework was presented at a conference held in Kunming in 2009 and then published his article "On micro, meso, and macro issues in engineering ethics" in 2010 (Li 2010). In spite of the fact that authors mentioned above do not agree among themselves on the micro–meso–macro framework, it is very important that there is a new direction or a hopeful trend which has been pointed in the fields of social science. All in all, concerning the relationship between a micro framework and a macro framework, there are four kinds of views or approaches.

The first approach adopted by individualists is reductionism, which, to some extent, seems to be a mainstream in Western economics, ethics, and philosophy. The second approach is holism, which is discredited by many famous scholars. With a reductionist or a holist approach, the micro–macro split becomes even sharper.

Due to the disadvantages of reductionism and holism, some scholars divest themselves of pure individualism or pure holism and try to compromise a micro theory with a macro theory, which means a "third way." The third approach, which is different both from the first and the second ones, is an integration, which is mentioned above. The fourth approach is to try to establish a micro–meso–macro framework which claims to address problems associated with the other approaches. From my point of view, with specifying a meso level, a micro–meso–macro framework is actually beyond or more advanced than the micro–macro framework. It should be noted that fourth way involves both a methodological aspect and an ontological aspect.

Engineering: Multiple Constructions at Three Levels

In this section, the author mainly focuses on the nature and characteristics of engineering. The author's aim is to establish and employ a micro–meso–macro framework in philosophy of engineering or more universally, in the field of engineering studies. As for the meaning and reference of the terms micro/meso/macro, different scholars hold different opinions. For instance, economists regard micro as individuals and firms, meso as regional economy or industrial economy, and macro as a state economy. From Jeurissen's point of view, "The micro-level is the level of the individual in the organization. Meso is the level of the organization, its structure and culture. Macro is the level of institutions, the market, government, cultural traditions and the like" (Jeurissen 1997, p. 247). Different from them, Enderle regards micro as individuals, meso as organizations, and macro as institutions

(Enderle 2002, p. 10). Although authors mentioned above agree upon the importance of a micro–meso–macro framework, there is no satisfactory opinion upon the meaning of a micro–meso–macro framework among them. In the following section, the main topic will be turned to the explanation of the nature and characteristics of engineering.

Engineering phenomena can be analyzed at three levels, micro level, meso level, and macro level. In philosophy of engineering, it is better to follow the example of economics and to regard the micro level as individuals and enterprises, the meso level as a region or an industry, and the macro level as a nation even the world. Philosophers of engineering should investigate not only micro engineering phenomena, such as individual conduct and production of enterprises, but also meso engineering phenomena, such as a kind of engineering as an industry, development in a region, and industrial clusters, and macro engineering phenomena, such as a state development and world development.

Potts, Dopfer, and Foster call a rule system a meso. They neglect the fact that different rules are applied at those three levels. In other words, it should be noted that there are micro rules, meso rules, and macro rules. So their definition of meso is not a fitting one. While the aim of sociologists is to explain all social phenomena, scholars who conduct research in the field of philosophy of engineering limit their task to explaining engineering phenomena. In order to investigate engineering phenomena, scholars should pay attention to engineering facts, engineering acts, and engineering results, which occur at all three levels. For philosophy of engineering, both engineering "reality" and engineering "fact" should be contained in the keyword pool. In 1992, I briefly suggested an engineering realism at an international conference held in Beijing. In 1995, John R. Searle published *The Construction of Social Reality*, which is regarded as a classic in academic circles today.

Generally speaking, three terms, *social reality*, *institutional reality,* and *social fact*, are of great importance. However, in the field of philosophy of engineering, scholars should not be satisfied with an abstract theory. From my point of view, philosophers of engineering must focus on enterprises as a kind of social reality, individuals as members of an enterprise, and engineering projects as a subclass of social fact. Only in this way can scholars develop a tenable theory based on engineering practice rather than a speculative theory of visionaries. On the basis of thinking in this way, it should be proposed that the main topic of philosophy of engineering is engineering construction.

It is obvious that engineering construction is a subclass of social construction. In 1966, Peter Berger and Thomas Luckmann published *The Social Construction of Reality*. The relation and difference between the title of Peter Berger and Thomas Luckmann's book and the title of Searle's book *The Construction of Social Reality* afford much food for reflection. The core is two transformations: the transformation from "social construction" into "construction" and the transformation from "reality" into "social reality." If the two transformations would be integrated into one, then "social construction of social reality" would reveal itself. I would argue that the nature of engineering consists in the social construction of engineering reality. The term "social" can be interpreted in a narrow sense or in a broad sense. The term "social" in its narrow sense means a social aspect which is parallel to an economic aspect, a technological aspect, a psychological aspect, and so on. The term "social" in its broad sense means integration among all aspects mentioned above. In order to distinguish its narrow senses from its broad sense, the term "social" and "societal" are respectively interpreted in a broad sense and in a narrow sense in the section below.

Briefly, social construction of engineering reality consists of a great number of aspects, technological construction of engineering reality, economic construction of engineering reality, societal construction of engineering reality, institutional construction of engineering reality, and so on. On the basis of the fact mentioned above, engineering or engineering reality means a multiple construction. Human beings construct engineering not only at a micro level but also at a meso level and a macro level. A "level" has not only a time dimension but also a space dimension. Therefore, the three levels, including a micro level, a meso level, and a macro level, have respectively three different time–space scales or measurements. At the last part of this section, a linguistic question concerning personal pronouns will be briefly discussed.

John R. Searle and Raimo Tuomela accentuate the importance of personal pronouns. Searle investigates the relationship between "I intentions" and "we intentions," and Tuomela investigates the relationship between "I-mode" and "we-mode." Searle points out that all genuinely social behavior contains collective intentionality on the part of the participants. He writes,

> [T]he problem I am discussing has a traditional name. It's called 'the problem of methodological individualism'. And the assumption has always been either you reduce collective intentionality to the first person singular, to 'I intend', or else you have to postulate a collective world spirit and all sorts of other perfectly dreadful metaphysical excrescences. But I reject the assumption that in order to have all my intentionality in my head, it must be expressible in the first person singular form. I have a great deal of intentionality, which is in the first person plural.
>
> (Searle 2001, p. 26)

Searle has acute theoretical eyesight. He considers that collective intentionality cannot be reduced to individual intentionality. He regards collective intentionality as a biologically primitive phenomenon that cannot be reduced to or eliminated in favor of something else (Searle 1995, p. 24).

Tuomela's view is parallel to Searle's view. Tuomela presents detailed analyses of I-mode and we-mode and shows that the we-mode is not reducible to the I-mode (Tuomela 2003, p. 93). Who am I? While in the span of a person's life "I" am constant, the denotation of "we" of which "I" am a member is continually changing. Thus, the relationship between "I" and "we" is a key topic in the field of social science.

In philosophy of engineering, the main range of investigation is narrowed to the relationship between "I" as a member of an engineering community and "we" as an engineering community such as an enterprise or a department of an engineering project.

Conclusion

It is natural that the keywords of philosophy of engineering consists of engineering phenomena, engineering facts, engineering reality, engineering design, engineering construction, engineering realism, and so on. In spite of a wide extension of the topic, I devote great attention to the topic of a micro–meso–macro framework and multiple constructions of engineering reality. In the history of philosophy, economics, ethics, and sociology, scholars debated whether to advocate a micro framework which is associated with individualism or a macro framework which is associated with holism. The debate concerns not only methodological issues but also ontological issues.

To investigate social phenomena, scholars developed four approaches, namely, micro-theory-based approach, macro-theory-based approach, micro–macro approach, and micro–meso–macro approach as a new kind of beyond micro–macro approach.

In 1990s, a few scholars who conducted research in the field of business ethics began to propose a micro–meso–macro framework in which the meso level becomes a key level. Recently, economists on evolutionary economics developed a micro–meso–macro framework that attracts our attention and inspires us to further efforts. Since the micro–meso–macro framework of engineering is thought of as a starting point, we can propound some new philosophical viewpoints. We regard micro–meso–macro framework as beyond the old-fashioned micro–macro split. The relationships among a micro level, a meso level, and a macro level is complicated and changeable. In contrast with a micro–macro framework, a meso level becomes a connecting or interpretive level in a micro–meso–macro framework. The presentation of the micro–meso–macro framework and multiple construction of engineering reality is of great importance and far-reaching.

From the linguistic point of view, it is not "I," "you," "he," or "she" as in the singular but "we," "you," and "they" as in the plural become subjects carrying out engineering practice. In an engineering community, individuals should be considered as its members. From the methodological and ontological point of view, an independent individual or a person as a member of the community is both identical and differential (Li et al. 2010, p. 292–304).

From the view of newly developed epistemology, it is not justification but creating, sharing, learning, organizing, and managing of knowledge that comes into the limelight which the author will expound in another article.

Because of the importance of engineering phenomena, engineering activity, engineering facts, and engineering reality, investigation of these aspects is of critical importance to the philosophy of engineering. We should stress importance on investigation of engineering facts and engineering reality in the context of a micro–meso–macro framework.

We should consider engineering in all its aspects, including a philosophical aspect, a technological aspect, a societal aspect, and a practical aspect. Engineering as a kind of social construction of social reality should be explained as a kind of multiple construction which is undertaken at micro, meso, and macro levels. The traditional micro–macro framework is obsolete. We should try to establish a new kind of micro–meso–macro framework.

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Chapter 3
Traditional Chinese Thinking and Its Influence on Modern Engineering and Social Development

Qian Wang and Qin Zhu

Abstract In premodern China, the traditional Chinese thinking pattern had a strong influence on the practice of engineering and on social development. This thinking pattern is still both influential and valuable today. In this chapter, we characterize the traditional thinking pattern from four perspectives: (1) at the ontological level, it presents itself as an organic entity; (2) at the epistemological level, it relies on intuitional experience; (3) at the methodological level, it highlights the notions of correlation and flexibility; and finally (4) at the ethical level, it advocates the morality of *yi dao yu shu* (mastering technique with dao) and pursues the harmony between a number of related contextual factors. Moreover, in this chapter, we indicate the influence of the traditional thinking pattern upon the modern practice of engineering in terms of planning, design, implementation, testing, and maintenance. Finally, we argue the case that the traditional thinking pattern can be recommended as a method to improve the professionalization of engineering practice, the quality of engineering education, and the development of qualified engineers.

Keywords Engineering culture • Thinking pattern • Chinese culture • Engineering practice • Development

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Characteristics of the Traditional Chinese Thinking Pattern

Discovering patterns of thinking among people from different regions, nations, countries, and cultural traditions has usually taken place within the study of anthropology, and cultural value systems have attracted a good deal of attention by cultural anthropologists (Graham 1984, pp. 527–536). The characteristics of thinking patterns exert imperceptible but far-reaching influence upon various social fields, including engineering practice and its relationship with society. In the history of China, the traditional value system or thinking pattern has continuously influenced Chinese engineering practice and successfully shaped engineering culture. Moreover, by way of dialogue with modernist perspectives influenced by Marxism, global technology, techno-scientific knowledge transfer, and economic exchanges, it has contributed to the modernization of Chinese engineering practice and to social development in China. A closer inspection of the traditional Chinese thinking pattern which is influenced by the Chinese traditions of Confucianism, Taoism, Chinese Buddhism, and Neo-Confucianism will therefore help us to better understand its significance to modern engineering and social development (Jenkins 2002). From the perspective of engineering, we may characterize the traditional Chinese thinking pattern in the following ways.

First, at an ontological level, it attaches great importance to organism. In his article "Dialogue between East and West," Joseph Needham points out that Chinese philosophy may be characterized as an organic naturalism, namely, a kind of organic understanding of nature, the theory of which is based upon a pattern of synthesis (Guan 2000, p. 36). This thinking pattern considers engineering practice as part of an organic entirety. Based on organic relationships, the thinking pattern designs and deals with the interactions between different parts within engineering practice and construes engineering practice itself an entirety. Dujiang Dam, one of the oldest large-scale irrigation projects in the world, is a typical case in this respect. It combines the three parts, "fish mouth levee," "flying sand weir," and "bottle-neck channel" as an organic unity, and thus enables them to perform the three functions organically: flood diversion, sand discharge, and irrigation supply.[1] As further examples, the ontology that considers engineering practice as an organic whole leaves its trace in the "combined kiln" in ancient Chinese production of ceramics and in the "casting by multiple furnaces" of Yongle Bell (Liu 1990, pp. 534–537; pp. 569–572). This organic ontology is able to eliminate the possible conflicts between diverse parts of engineering practice so as to achieve a complete synthesis.

Second, at an epistemological level, the traditional thinking pattern emphasizes the importance of intuitive experience. It grasps tacit knowledge and know-how in engineering practice using the theory of *yin* and *yang* and *wuxing* (five elements) as

[1] In the year 256 BC, Li Bing and his son directed the construction of the Dujiang Dam to control flooding on the Chengdu Plains in Sichuan Province. This construction in water conservancy made rationalized irrigation supply, flood diversion, and sand discharge possible. The dam still plays a tremendous role in this regard (cf Wang et al. 2008, p. 920).

the interpretive model. Thus, *wuxing* should not be viewed as a system of five fundamental elements of matter, rather as an early attempt to classify the processes in nature. This classification is based not on patterns but on the properties of the processes. The *wuxing* system was convenient and practical, for it makes use of familiar materials to identify and represent processes (Chen 1996, p. 201). The relevant know-how could not be achieved without intuitive experience in such practices as assembling wood components in ancient Chinese architecture, configuring the duration in smelting, and adjusting the temperature of water in filature. In these practices, one may detect a great deal of tacit knowledge, which is difficult to explain with words. Therefore, this tacit knowledge requires metaphors and analogies to enlighten the understanding and communications between master and apprentice. Richard Li-Hua has made a comprehensive comparison between the two components of technological knowledge: tacit and explicit or more precisely codified knowledge. According to Li-Hua's study, tacit knowledge is a kind of "subjective, simultaneous (here and now), and analogic (practice)" knowledge originating in bodily "experience," while explicit codified knowledge is a kind of "objective, sequential (there and then), and digital (theory)" knowledge originating from the "rationality" of the mind (Li-Hua 2009, pp. 18–22). Because the traditional Chinese thinking pattern contains an interpretation of the specific links and mechanisms of intuitive experience and develops a system of categories different from the Western logic and logical thinking patterns, it may be more effective in applying tacit knowledge in engineering practices.

Third, at a methodological level, the traditional Chinese thinking pattern adopts methods that focus on the correlations and flexibilities in coordinating various conflicts among engineering practices. For example, in agricultural cultivation, the harmony between *tian* (sky), *di* (earth), and *ren* (people) is paid great attention on the basis of adapting to the conditions of space and time. In hydraulic engineering, the thinking pattern makes good use of the specific structure of the geographical landscape, while in mechanical engineering it emphasizes utilizing external forces ingeniously. Mechanical inventions like *yuxi* (fish basin),[2] *zouma deng* (shadow picture lamp),[3] and *zhinan che* (southward-pointing cart)[4] all demonstrate mechanical insgenuity. In architectural engineering, people emphasize

[2] *Yuxi* (fish basin): When rubbing the handles of a fish basin with your hands, symmetrical vibration will generate around the basin; thus, the corresponding harmonious vibration of the water in the basin will form pretty sprays and splashing globules. Meanwhile, a buzz will be generated when the regular cylindrical sheet copper on the basin wall vibrates (cf Shanghai News and Press Bureau 2007).

[3] *Zouma deng* (shadow picture lamp): The zouma deng, shaped like a miniature pavilion with upturned eaves, features an inner wire shaft fitted with paper vanes. The heat current from the lit candle rotates the shaft, setting a paper cutout in a merry-go-round motion (cf Hermes 2009).

[4] *Zhinan che* (southward-pointing chariot): The chariot is a two-wheeled vehicle upon which is a pointing figure connected to the wheels by means of differential gearing. Through careful selection of wheel size and track and gear ratios, the figure atop the chariot will always point in the same direction, hence acting as a nonmagnetic compass vehicle (cf Wikipedia entry "southward pointing chariot," http://en.wikipedia.org/wiki/South_Pointing_Chariot).

feng shui (Chinese geomancy[5]), including harmony between structures, their surroundings, and ecological environment. Ancient Chinese gardens, influenced by Daoist philosophy, were built for reflection and meditation, guided by a strong desire to achieve harmony with nature (Johnson et al. 2008, pp. 27–28).

Fourth and last, at an ethical level, the traditional Chinese thinking pattern puts forward the principle of *yi dao yu shu*, which attempts to maintain the harmony between related components in engineering activities. Traditional Chinese culture encourages those engineering activities that benefit the nation's economy and people's livelihood and set moral requirements, such as *zhengde* (rectification of virtues), *liyong* (development of ability), and *housheng* (strong protection of life), as the basic values and standards. It criticizes engineering projects that *lao min shang cai* (waste labor and money) and those *qi ji yin qiao* (magical skills and improper cleverness) that ruin social morality. Since ancient times, China has had an intellectual tradition of restraining luxury, advocating frugality, and curtailing extravagant engineering projects that are *da xing tu mu* (building large-scale construction projects). From the Daoist perspective, luxury makes one proud, but its satisfaction is only temporary since it also stimulates the appetite for more. Daoists believe that enduring happiness is to be found in a simple and frugal life, and therefore, Daoism encourages people to embrace simplicity and purity (Li 2005, p. 162). In a European context, similar values are put forward in the philosophy of Jean Jacques Rousseau in particular in his first discourse "Discourse on the Moral Effects of the Arts and Sciences" from 1750. Similarly, Moism considers all things not necessary to basic survival as extravagant. Mozi wanted to establish a society that had no frills, no luxury, no sophistication, and no waste. He even argued that "the time spent on learning, performing, and enjoying music can be better used to tend to farming, weaving, and governing" (Liu 2006, p. 21). This engineering ethical idea not only purifies contemporary social morals but also sheds light on the ways to deal with ethical problems in later engineering activities.

Thus, it can be seen that the characteristics of traditional Chinese thinking pattern have coordinated the relationship between engineering activities, social life, and natural environment. They redounded to the standards of ancient engineering and may continue to contribute to the development of modern engineering practice, which is explored in the next section.

Influences of the Traditional Chinese Thinking Pattern upon Modern Engineering Practice

The scientific theories and technological principles of modern engineering activities are rooted intellectually in the West. In the late nineteenth and early twentieth centuries, a number of Western engineering books were translated into Chinese by

[5] The geomantic omen theory refers to a comprehensive principle of appraisal of environmental considerations in the planning and designing of buildings in ancient China such as topography, physiognomy, view, climate, and ecology.

Christian missionaries as part of their efforts to modernize China (Zhu 2010, pp. 85–107). The rendered term of *gongcheng,* which involves scientific control of nature, refers to engineering in the modern sense. Since modern engineering practice developed within the Chinese cultural environment, the so-called "soft" social disciplines, such as, for instance, management, organization, and institutional structures, are somehow more unavoidably localized and adapted to local contexts in contrast to the "hard" engineering disciplines (scientific theories and technological principles) which tend to be decontextualized. Chinese engineers and technicians, starting from the actual conditions of their cultural background, solved new problems through engineering practice. They tried to seek better and faster ways of development on the premise of adherence to scientific theories and technological principles. In this process, the traditional Chinese thinking pattern is playing a positive role while, at the same time, having negative impacts as well.

The influences of the traditional thinking pattern on modern Chinese engineering practice are to be found mainly in planning, design, operation, management, and maintenance. In developed countries, engineering planning and design, to a large extent, are influenced by market supply and demand and technological standards; hence, mobilization of money and resources is strictly limited. However, the planning and operation of large-scale modern Chinese engineering projects have benefited from mobilization and support from within the social organism due to favorable organic relations in society. In this way, shortages of economic and technological capacities have been compensated for. Historically, China had been tied to a tradition of "grand unification projects," such as, for example, the construction of the Great Wall, the Grand Canal, and the measurement of the geodetic meridian. In contemporary China, this tradition has been kept and is practiced in engineering planning and design for national defense, aerospace, and large-scale reservoirs. In fact, this practice has notable achievements in all of the above fields. For example, in the programs of *liangdan yixing* (two bombs and one satellite),[6] many intellectuals were included in a research team with great passion ("red and expert"), making it possible for programs to accomplish their goals very quickly (Andreas 2009).

In the engineering stages of operation, testing, and maintenance, engineering practice in China localizes engineering knowledge and operational principles by means of technological innovation and reformation. This includes employing appropriate alternative materials and tools, reassembling technological components, and accumulating technological experience and skills. In Chinese engineering management, the incentives provided to excellent workers and technicians are mainly based on their achievements in technological invention and innovation rather than their labor productivity. This is a modern echo of the traditional Chinese notion of *gong*

[6] *Liangdan yixing* (two bombs and one satellite) programs: Two bombs refer to the atomic bomb and hydrogen bomb, while one satellite refers to China's development of its artificial satellite. *Liangdan yixing* programs are considered as the "grand unification projects" through using the unified (organic) political system to organize the limited resources in the highly effective way.

you qiao (crafts display ingenuity). Li Ruihuan,[7] Ni Zhifu, and Wu Guixian all began their careers in Chinese leadership through their technological invention and innovation.

In the 1960s, a model of engineering management with local cultural color, the *Angang (Anshan Steel Company) Constitution,* was formed. Among the principles put forward in the *Angang Constitution* was a principle stipulating that managers should participate in physical labor and workers should take part in management to identify and reform unreasonable rules and regulations. This model constitution emphasized the necessity of the cooperation between managers, workers, and technicians. Yun Chen (2009) gives a historical-economic review of how the *Angang Constitution* originated:

> In March 1960, Mao Zedong gave instructions to establish the system saying “two participants, one reform and three unions” regarding the management of the Anshan iron and steel works. The “two participants” meant that executives participated in labor and laborers participated in management, “one reform” showed that unreasonable prescriptions and institutions were reformed, and “three unions” indicated that the three of laborer, executive and engineer were united. By the state-owned industrial enterprise policy act (commonly known as industrial 70 articles), they decided that this management system was formerly approved and an employee representative meeting system under the directives by communist committee of the factory was established. The aims of the act were displayed that the administration and management sections of the enterprise was supervised and the bureaucratic system was overcome, and the democratic management system of the enterprise was improved.
>
> (Chen 2009, p. 242)

Adopting the principles put forward in the above quote with an eye to correlations and flexibilities, this traditional thinking pattern may be seen as being able to coordinate the interpersonal relations in engineering activities and find problems in the early stages of implementation. However, at the same time, the traditional Chinese thinking pattern also exerts a negative influence upon modern Chinese engineering practice. By means of this way of thinking, engineers may find it easier not to examine and apply scientific principles and rigor to engineering activities; they may fail to follow precisely the delicate engineering management rules and technological standards; their excessive reliance upon direct experience may disguise the potential risks of engineering. These limitations have been an ongoing concern in engineering in China and may be said to have been gradually overcome with great effort in modern engineering practice. For instance, T. N. Jenkins argues that even though Chinese traditions were “based on the ideals of harmony, human perfectibility and systematic fit within natural systems and processes,” “the Chinese

[7] Li Ruihuan was a politician active in the late twentieth century and early twenty-first century in China as a member of the Standing Committee of the Political Bureau of 15th Central Committee of the CPC (until November 2002) and the chairman of the 9th National Committee of the Chinese People’s Political Consultative Conference (until March 2003). As the inventor of the “simplified calculation method” which updated the traditional “lofting method” in carpentry, Li was known as “young Luban,” a legendary master carpenter in ancient China. Then he rose up the ranks of the construction industry and Tianjing politics (cf “Li Ruihuan” entry in Wikipedia).

worldview also contains strong worldly and utilitarian elements at the popular level" that would then neglect the inherent risks within the society such as environmental degradation risks (Jenkins 2002, pp. 39–52).

Influences of the Traditional Chinese Thinking Pattern on the Relationship Between Modern Engineering and Society

The influences of the traditional thinking pattern on the relationship between modern engineering and society are evident in the requirement for engineering quality, the evaluation of engineers and technicians, and the effects of engineering education. The ancient concept of *yi dao yu shu* requires the unity of both economic and social benefits, the unity of both short-term and long-term interests, and the unity of partial and holistic interests in engineering work. Engineers and technicians are urged to hold the consciousness of *dawo* (greater self), fulfill the concept of *zhixing heyi* (the unity of knowledge and action), and thus relate the concepts and ethical principles in engineering ethics with practice. This sort of idea has played a positive role in coordinating the relationship between engineering and society in general in modern China.

The concept of *zhixing heyi* was first formulated by Chinese philosopher Wang Yangming in the Ming Dynasty (1368–1644 CE). Wang argued that knowledge and action were truly one thing. In the book *Instructions for Practical Living*, he used the term *zhixing heyi* to mean that there was no way to separate knowledge from action since "*zhi* is already a kind of action because to know something has less to do with representing it mentally and more to do with determining how one relates to it" (Frisina 2001, p. 97). In the ethical sense, it refers to the practical application of ethical principles to social actions (Munro 2009, p. vii).

From the 1950s to the 1960s, Chinese political and ideological education impacted greatly on engineering management, which provided a modern example of the ancient concept of *yi dao yu shu*. This combination of the modern and ancient needs careful analysis. On the one hand, its simplified popularization sometimes weakened the demands of developing engineering activities by abiding exactly by economic laws and technological standards; on the other hand, in a cultural environment which emphasized correlations in social organisms, its appropriate application enhanced the sense of social responsibility and working enthusiasm among engineers and technicians. However, the concept of *yi dao yu shu* had some positive consequences, such as avoiding the temptation to pursue short-term profits and also fulfilling the role of coordinating the relationship between engineering and society. Therefore, few cases were reported in which either the engineers or technicians neglected their duty or cases where severe technologically related accidents occurred in enterprises due to the sheer pursuit of economic profit. Since the 1980s, when a market economy has come to prevail in China, the significance of the traditional idea of *yi dao yu shu* applying to the relationship between engineering and society has become even more obvious.

Because they originated prior to the market economy, traditional Chinese engineering ethics and moral regulation are not sufficient to fulfill their duty in a market economy. Due to a lack of practical restrictions and efficient regulating mechanisms, the ethical awareness and sense of social responsibility among engineers and technicians were dwindling, and as a consequence many problems concerning engineering quality and security arose. Currently, as a response to this challenge, constituencies among Chinese academics and engineering educationalists have begun to pay great attention to the study of engineering ethics. In November 2004, the Chinese Academy of Engineering, together with the academies of engineering in Japan and South Korea, issued a "Declaration on Engineering Ethics" that included the "Asian Engineers' Guideline of Ethics."[8] It may prove in time that neglecting the positive side of the traditional Chinese thinking pattern and reducing the mechanism of *yi dao yu shu* will most likely cause future problems.

As an intellectual resource, the traditional Chinese thinking pattern is of value in coordinating the relationship between modern engineering and society. It is not only beneficial to the sound development of modern Chinese engineering activities but also provides a kind of clue for solving similar problems in other countries. The sphere of influence of modern engineering activities is becoming increasingly wider. These activities are likely to bring about economic, political, cultural, ecological, and environmental problems on a trans-regional or even multinational scale. Thus, a holistic thinking pattern that aims at correlations is needed to change the tendency of *yilin weihe* (beggar-my-neighbor or shift one's troubles onto others). Economic, cultural, and social differences between countries may result in "boundary-crossing problems" for engineers. Solutions to these problems must avoid absolutism and relativism and should find a way between rigor and moral laxness (cf Harris et al. 2008).

The increasing division of labor based on specialization and complexity makes it harder and harder to define the ethical responsibilities of engineers and technicians at every concrete stage of an engineering project or in engineering work. The phenomenon of *normal accidents* coined by American sociologist Charles Perrow implies that the complexities of technological systems may cause difficulties in estimating technological risks and in finding appropriate agents to avoid them (cf Perrow 1984). Therefore, it requires enlightening the moral consciences of engineers and technicians and applying *phronesis* to deal with the relationship between individual and collective interests and social responsibilities. *Phronesis* concerns the analysis of values – "things that are good or bad for humans" – as a point of departure for action (Flyvbjerg 2006, pp. 71–72). It has been widely used as an interpretive methodology in the social sciences, in dealing with problems concerning uncertainties and risks. As a context-specific, collective-concerned, and action-oriented methodology, it will inspire engineers to make proper and wise decisions in complicated socio-technical contexts. In Chinese engineering ethics education, the prospects of applying the requirements of *zhixing heyi* and cultivating the ethical consciousness

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[8] This guideline emphasized the importance of "cherishing the Asian cultural heritage of harmonious living with neighboring people and nature."

in engineering are presently very promising and would therefore most likely be able to play their due roles. The principles developed in engineering ethics only constitute the "soft constraints" and must be complemented by the guarantee of corresponding institutions and constituencies. However, the flexible methods within the traditional Chinese thinking pattern will sometimes weaken the effects of institutional restrictions. This kind of shortcoming should be remedied over time in contemporary engineering practice.

The steady development of contemporary engineering requires the active use of factors from local cultural resources that favor coordination between engineering and society. Culture is capable of influencing something as simple as the placement of light switches or as complex as the overall design of a structure. If cultural issues are not explored prior to the implementation of a design, changes to accommodate them later may be more expensive. Designs used in some countries are inappropriate for other countries due to cultural nuances (Yates 2007, pp. 23–24). The influence of the traditional Chinese thinking pattern upon modern engineering and social development is a valuable technique whose theoretical and practical significance deserves further exploration.

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Chapter 4
Engineering and Development in Modern China: Challenges and Responses

Xiaonan Hong and Li Ma

Abstract Over the past several thousand years, China has made extensive and unique contributions to engineering and technological fields such as agriculture, food, textiles, architecture, metallurgy, ceramics, and medicine. In doing so, it has added significantly to the development of Chinese culture and all of human civilization. The Four Great Inventions of ancient Chinese people—papermaking, typography, gunpowder, and compass—are applied throughout the world. It is estimated that in 1820, China accounted for up to 30% of the world's GDP. However, for various reasons, Chinese engineering and technology stalled as China entered modern times and fell far behind developing Western countries. After being defeated by Western powers with their warships and cannons in the latter half of the nineteenth century, the secluded feudal Qing Dynasty began using some science and technology transferred from the West. These methods and machines provided a foundation for modern Chinese industry. But due to political corruption and recurring invasions by imperialist countries, China remained very weak in engineering, technology, and industry, falling behind developed countries in Europe and North America. This chapter analyzes the relationships between engineering and the development of modern Chinese society from the perspective of historical development. Based on a "challenge-response" model approach to theorizing the codeveloping processes of engineering and modern Chinese society, key engineering projects and representative engineers are selected for detailed analysis.

Keywords Engineering • Engineers • Modern China • Development • Chinese engineers

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Introduction

In the study of modern Chinese development, a prevalent explanation guiding development choice is referred to as the "challenge-response" theory. In the 1950s, John King Fairbank proposed the "impact (from the West)-response (from the East) theory," which became a very popular and controversial long-standing theory in American Sinology (Hong 2009, p. 255). The main problems with this theory are that it generalized and exaggerated the impact of Western invasions on China and overestimated the "superstable structure" of Chinese society, ignoring the dynamic role that Chinese society played during early modernization. After John King Fairbank put forward his "traditional-modern model" in the 1960s, Paul A. Cohen and others, students of Fairbank, proposed the "China-centered approach" in the 1970s. In this approach, they advocated seeking motivation for changes and advancement mainly from within Chinese society (Hong 2009, p. 255). This chapter will analyze the codeveloping processes of engineering and modern Chinese society based on the "challenge-response" model. Table 4.1 below provides an overview of the processes.

Premodernization Period (1840–1919): The Period of the Spread of Western Learning to the East, Saving and Survival

The major challenges for China in this period were the two Opium Wars (1839–1842 and 1856–1860) and the introduction of modern science and technology from the West. The response of Chinese intellectuals can be characterized as: saving and survival, saving and enlightenment.

In the West, natural science developed stage by stage from the Renaissance up to and through the Industrial Revolution. Western science was introduced into China over about two and a half centuries, starting with the Italian Jesuit missionary Matteo Ricci 's arrival in Guangdong Province in 1583. It continued through to the end of the Opium War in 1840. In 1601, Matteo Ricci's audience in Beijing with the Wanli Emperor of the Ming Dynasty occurred when modern science was emerging in Europe. Scientific achievements, such as Galileo's discoveries through experiments and mathematical methods, were spreading into China, hastened by European missionaries in China during the Wanli Era of the Ming Dynasty. During this time, China lost its dominant position as a civilization that leads scientific and technological developments. Instead, this became a period during which the spread of learning was from the West to the East.

During the 260 years of this period, modern science and technology developed rapidly in Europe and was gradually transferred to China. In contrast, China was declining in its comprehensive strength day by day, stubbornly sticking to its policy of seclusion. After two and a half centuries of cultural invasion, many Western

Table 4.1 Engineering and Development in Modern China

Historical period	Development as	Major views of communities
1840–1919 Premodernization—the period of the spread of Western learning to the East; salvation and survival	Saving and survival Learning from foreigners to compete with foreigners Chinese knowledge as the body, Western learning for uses	1913: Chinese Engineering Society 1915: Science Society of China 1918: Chinese Mechanical Engineering Society (CMES) *Celebrated engineer*: Zhan Tianyou (詹天佑) *Key projects*: Beijing-Shenyang Railway, Beijing-Zhangjiakou Railway
1919–1949 Change from traditional society to modern society	Saving and survival Saving outweighing enlightenment 1930s: modernization or Westernization	1919: science and democracy 1930s: modernization 1931: Chinese Institute of Engineers; the Period of the Westernization Movement *Celebrated engineers*: Hou Debang (侯德榜), Mao Yisheng (茅以升), etc. *Key project*: Qiantang River Bridge
1949–1978 Change from traditional society to modern society—the period of independent development	Marching toward science Learning from all countries Four Modernizations (agriculture, industry, national defense, science and technology)	*Celebrated engineers*: Li Siguang (李四光), Qian Sanqiang (钱三强), Qian Xuesen (钱学森), etc. *Key projects*: Qinghai-Tibet Highway, Wuhan Changjiang River Bridge, Nanjing Changjiang River Bridge, Guizhou-Guangxi Railway, Chengdu-Kunming Railway, Baoji-Chengdu Railway
1978–2011 Change from traditional society to modern society—the period of reform and opening up	Modernization Sustainable development 2003: scientific concept of development	1980s: Chinese character information processing and revolution of printing 1990s: strategy of invigorating the country through science, technology, and education Chinese Academy of Engineering, constructing an innovative country 2010: the Education and Training Program of Excellent Engineers *Key projects*: Qinghai-Tibet Railway, Beijing-Jiulong Railway, West-East Gas Transmission, West-East Electricity Transmission, North-South Coal Transport, Three Gorges Key Water-Control Project, Xiaolangdi Key Water Control Project, South-North Water Transfer, Linhuaigang Flood Control Project, Gezhouba Key Water Control Project, Longyangxia Hydraulic Power Plant, Qinshan Nuclear Power Plant, Qinling Tunnel, Hangzhou Bay Bridge, Beijing-Shanghai Express Railway

powers knew how frail and corrupt China was, so they resorted to force and invaded the country. Once a great military power, China was easily defeated in the Opium War by the United Kingdom, the first industrialized capitalist nation in the West. From that point on, China was "carved up" and exploited by other countries. China's failure in the First Opium War provoked some ardent patriots into exploring ways to save and strengthen the country. They ascribed China's failure to the advancement of Western technology, i.e.,

> Their steamships and telegraph are fast enough to travel a thousand li (one kilometer is two li) in a second; their weapons and military equipment are so refined that they are 100 times more effective; their artillery shells can overrun all fortifications, without being restricted by water or any passes; in several thousand years we have never met adversaries strong and formidable like them.
>
> (Wu 1905, p. 45)

As the period 1583–1840 saw the spread of Western learning to the East, the time from China's failure in the Opium War in 1840 to its failure in the Sino-Japanese War in 1895 was the period of the Westernization Movement initiated by the government. At the beginning of this period, when China was forced to open five trading ports, Protestant missionaries came in large numbers, preaching the Gospel and introducing Western civilization's material, scientific, and cultural underpinnings to Chinese. The Qing government was still posing as the Celestial Empire, not eager to make any progress at all, so China was put in the passive position of having to import innovation, even via war. China was reduced to a semicolonial society inch by inch. A few men with insight such as Lin Zexu (林则徐), who proposed "learning from the adversaries to beat the adversaries," and Wei Yuan (魏源), who advocated "learning from foreigners to compete with foreigners," started to reflect on the general situation. After failing in the Second Opium War (1856–1860), the Qing government ascribed this failure to the advanced armament of the foreigners. A Westernization Faction developed in the gerontocratic group in which there were many important officials, such as Zeng Guofan (曾国藩), Li Hongzhang (李鸿章), and Zuo Zongtang (左宗棠), led by Yixin (奕䜣)—Prince Gong.

To tackle the Taiping Rebellion, the Westernization Faction introduced a series of policies such as *learning from foreigners, Westernization*, and *self-prosperity with Western-developed methods*, known historically as the "Westernization Movement" (Liu 2003, p. 42). The Westernization Faction initiated an epoch of saving the country by studying and promoting science and technology in China, enabling the transition from a traditional Chinese educational system to a modern educational system. Later, Liang Qichao (梁启超) put it clearly, "the essence of political reform is education, while to educate people we need to run more schools" (Liang 2002, p. 24), and so he believed that the strength of a nation depended highly on the education of the citizens. In its essence, his proposition of educating people and advocating learning from the West was scientific and democratic enlightenment, which to some extent, became the theoretical basis of all factions advocating saving the country through education. In the Westernization Movement, China admitted officially for the first time that it needed to study Western science and technology, learning and borrowing voluntarily from modern Western science and technology.

The School of Combined Learning (1862) was established as the first educational institution that taught scientific material developed by European and American academics; at the Translation Institution (1868) founded by Jiangnan Manufacturing Bureau, Western science books were translated into Chinese; the first university in China, Peiyang College (Tianjin University now), was founded (1895); a group of young people including children were designated to study in America (1872), among whom was Zhan Tianyou, who was to become a well-known railway engineer. The dominant idea of the Westernization Movement was "the Chinese knowledge as the body, the Western learning for uses," put forward by Zhang Zhidong, an important figure in the rising Westernization Faction (Ding and Chen 1995, p. 255). The faction aimed at learning and applying practical Western manufacturing techniques, while maintaining and strengthening traditional Confucianism, the system of legal and cultural authority in Chinese feudal society. The Westernization Movement started from developing military industry by importing, on a large-scale, Western technologies and equipment. China entered the early stages of what could be termed "modern industrialization" through the introduction of foreign technologies, developing military industry operated by the government, and promoting commercial industry supervised by the government. Bureaucratic capital and national capital were accumulated during this period, and the industrial working class came into being, (according to statistics in 1894, there were well over 90,000 industrial workers), enlarging the social influence of modern science and technology. However, the Westernization Movement did not change the feudal characteristics of Chinese economic society. On the contrary, together with the economic invasion of Western powers and the monopolization of foreign-invested industry in China, the movement accelerated the collapse of China into a semicolonial and semifeudal society. During the Sino-Japanese War, the Chinese Beiyang Navy was completely annihilated by Japan, whose reform movement was 6 years later than the Chinese Westernization Movement. Hence, it could be claimed that the Westernization Movement failed in China.

Through the Westernization Movement, modern industry was developed to some extent in China. The success of the 1911 Revolution encouraged some Chinese people in the field of engineering to save the country with science, working hard for the prosperity of the country. They planned to found a national academic organization for engineers, so as to promote the development of engineering in modern China. Under the pressure of mass movements, China took back the right of mining from Western powers in the year 1905. National capitalist industry and commerce developed rapidly when the Western powers were occupied with fighting in the First World War. Science and production technologies were imported on a large scale from the West. The number of industrial workers increased from approximately 500,000 in the year 1911 to over two million by 1919.

Zhan Tianyou founded Chung Hwa Society of Engineers in Guangdong Province in 1912; Yan Deqing (颜德庆), Wu Jian (吴健), and others founded the Chung Hwa

Engineers Society in Shanghai; Xu Wenjiong (徐文炯) set up the Railroad Engineers Union, also in Shanghai. The three organizations reached an agreement and merged into the national Chung Hwa Institute of Engineers in Hankou in August 1913, with Zhan Tianyou elected as the first president because of his prestige. The chief aim of the institute was for engineers to communicate with each other, to study engineering, and to develop Chinese engineering and construction as a collective effort. There were 146 members when the institute was founded. In March 1918, a group of Chinese students and trainees who studied engineering in the USA negotiated Chinese Engineering Society, with Chen Ticheng (陈体诚) elected as president, and attempted to organize engineers and technicians for the further development of modern Chinese industrial technology. There were 84 members when the society was founded. Only five annual conferences were held by this society in the USA, but the participants were talented, vigorous, and well-educated young people equipped with modern knowledge of science and technology, so there was always a very lively atmosphere at the conferences, and the number of members enrolled reached over 1,000 in a couple of years. Since many members came back to the country in the following years, the annual conferences were held in China after 1935 (Shi et al. 2009). In the premodernization period, the most prominent project in China was the Beijing-Zhangjiakou Railway constructed under the direction of Zhan Tianyou.

Pillar I[1]: Zhan Tianyou and the Beijing-Zhangjiakou Railway

In early times, Chinese railways were inseparable from the famous railway engineer Zhan Tianyou, born in Nanhai County, Guangdong Province, in 1861. When he was only 12 years old, he went to study in the USA. As a student, he made up his mind to enrich his homeland through building railways. In June 1881, he graduated with the highest score from Yale University, specializing in railway engineering. He came back to China in August 1881. When he was in charge of the construction of the railway between Tanggu and Tianjin, and also Luanhe Bridge, he demonstrated his engineering talents for the first time, which were also recognized and admired by the sometimes-arrogant foreign engineers. Zhan Tianyou directed many significant projects throughout his life, with the most prominent contribution being the construction of the Beijing-Zhangjiakou Railway.

In May 1905, the Beijing-Zhangjiakou Railway Bureau and Engineering Bureau were founded, with Chen Zhaochang (陈昭常) appointed the general director and Zhan Tianyou the vice director and chief engineer. When Zhan Tianyou was promoted to general director and chief engineer, he knew well what an arduous job it was. He later wrote to his teacher Mrs. Northrop in the USA:

> If the Beijing-Zhangjiakou Project turned out to be a failure, it would not only be my misfortune, but also the misfortune of all Chinese engineers and a great loss for China. Before and even

[1] The pillars are to be understood as very important historical events in different periods of engineering development in modern China.

> after I undertook this project, many foreigners declared that Chinese engineers would never be able to handle the stonework and caves between Beijing and Zhangjiakou, but I'm sure that I could succeed.
>
> (Zhan 1989, pp. 99–100)

This is the embodiment of Chinese intellectuals' unswerving loyalty to the homeland and their sense of responsibility for the nation. On September 24th, 1909, Beijing-Zhangjiakou Railway was completed, 2 years ahead of schedule, costing only one fifth of the expense estimated by foreigners. This railroad connected Beijing and northwestern China, dashing the desires of the UK and Tsarist Russia to construct the railroad. In the meantime, Chinese confidence was considerably boosted because they had built the railway themselves.

Further Developments in the Premodernization Period

The adoption of a modern education system was one of the greatest achievements of the constitutional reform and modernization. On the first day of the reform, orders were given to build Peking Imperial University and middle schools, primary schools, and industrial schools in the provinces. Orders were also given so that translation institutes should be set up, invention and creation should be encouraged, and patent right should be protected. Although the reform turned out to be a failure, with most policies not implemented, the encouragement of building schools was retained up to the year 1905 when the imperial examination system was abolished, and the various disciplines of modern science and technology were formally adopted into education. At the same time in China, the socialization process of a scientific organizational system began to take hold. A series of academic and scientific institutions were founded, such as the Chinese Geographical Society (1909), Chung Hwa Institute of Engineers (1913), Geological Survey Institute (1913), the Science Society of China (1915), and the Chung Hwa Medical Association (1915).

In the late nineteenth century, advanced scientific ideas such as the theory of biological evolution in Thomas Henry Huxley's *Evolution and Ethics* translated by Yan Fu (严复) and the economic thought in Adam Smith's *The Wealth of Nations* exerted enormous influence on educated individuals, urging the awakening of a Chinese nation. Since the twentieth century, the Mind Emancipation Movement and New Culture Movement, characterized by the slogan of science and technology first advocated in May Fourth Movement, accelerated the spread of science and social changes. Founded in 1915, the Science Society of China became the most influential scientific organization that lasted for the longest time in modern China, aiming to "unite the like-minded and conducting academic research so as to develop science in China." It encouraged the members to put emphasis on the spread of Western scientific ideas when undertaking scientific studies. Chinese scientists represented by the mathematicians Ren Hongjun (任鸿隽) and Hu Mingfu (胡明复), the geologist Yang Quan (杨诠), and the chemist Wang Xinggong (王星拱), etc., had a profound influence on Chinese when they systematically and continually introduced Western scientific knowledge, thoughts, methodology, and spirit to China. They introduced scientific concepts and modern scientific methods such as experimentation, induction, and deduction into China, which not only changed the knowledge structure of Chinese people but also greatly influenced their mode of thinking. During this period, key projects in China were the Beijing-Shenyang Railway and Beijing-Zhangjiakou Railway. Generally speaking, science and technology in this period of China were comparatively underdeveloped, staying far below the world's most advanced level, in stark contrast to the extensive scientific achievements in ancient China.

Change from Traditional Society to Modern Society (1919–1949)

The consequences of challenge and response during the previous stage continued into this period. The Westernization Movement occurred when China pursued Western-advanced armaments (material culture, culture of utensils), reflected on the reasons for China's successive failure, and studied advanced Western science and technology. The 1911 Revolution broke out when China imitated Western systems and cultures and experienced the reform movement which led to the Hundred Days Reform of 1898; the May Fourth New Culture Movement came when China pursued spiritual culture and value, shouting the slogans "Down with Confucius and Sons," and "Re-evaluate all Values." This period, as Mao Zedong (毛泽东) put it, was "the Period of New Democratic Revolution." The major challenges for China were the systematic import and assimilation of Western science and technology, as well as the invasion of Japan. Chinese intellectuals responded by launching the May Fourth New Culture Movement, during which they replaced the traditional Chinese doctrine of Confucius and Mencius with utter devotion to science and technology in pursuit of "democracy" and "science," from which came the theme of saving the country with science.

The outcome of the May Fourth Movement was "saving outweighing enlightenment." This meant that saving the country from collapse was more important than enlightening the Chinese people to Western civilization, and so the Chinese Enlightenment Movement was discontinued, and the criticism of feudal tradition was incomplete. Since 1937, the war unleashed by Japan not only destroyed the modern Chinese economy but also devastated modern Chinese science and technology in its initial stage. Almost all science-technology sectors were at a standstill up to 1949.

The annual conferences of the Chinese Institute of Engineers provide insight into the development of Chinese engineering technology during this period. In August 1931, the Chung Hwa Institute of Engineers and Chinese Engineering Society agreed to a merger and founded the Chinese Institute of Engineers at their annual conference in Nanjing, which became the headquarters of the new institute. The aim of the institute was to unite people within the engineering community, to develop Chinese engineering through shared effort, and to research and enhance engineering. With 2,169 members at its foundation, this institute was the largest of the time. In the following decade and beyond, the institute contributed significantly to the development of modern Chinese engineering and technology and the unity of Chinese engineers and technicians.

When the number of members reached over 16,000 in 1949, the institute became the largest society of science and technology in modern China with the longest history and largest number of members. Most activities organized by the institute were annual conferences, at which participants read their papers and discussed key construction issues in China. For example, the issue of engineering education in 1926, the issue of cities in 1928, the issue of industrial development in 1936, the patent issue in 1940, the issue of industrial standardization in 1941, the issue of constructing northwestern China in 1942, the issue of constructing southwestern China in 1943, and the issue of transportation in wartime in 1945. In encouraging innovations and creations, the institute awarded gold medals of engineering honor to Hou Debang (侯德榜) in 1935 for his great contribution in soda manufacturing and his book *Manufacture of Soda*, to Ling Hongxun (凌鸿勋) in 1936 for directing the construction of the hardest and most dangerous parts of Longhai Railway and Aohanlu Railway, to Mao Yisheng for designing and directing the construction of the well-known Qiantang River Bridge in the year 1941, to Sun Yueqi (孙越琦) in 1942 for prospecting the northwestern oil field, to Zhi Bingyuan (支秉渊) in 1943 for his success in developing diesel engine in China, to Zeng Yangfu (曾养甫) for directing the construction of Chengdu Airport in 1944, to Gong Jicheng (龚继成) in 1945 for directing the construction of Ledo Road and the Pipeline, to Li Chenggan (李承干) in 1946 for his contribution to ordnance industry, and to Zhu Guangcai (朱光彩) in 1947 for his success in leading people to close up the break in Huayuankou in Huanghe River (Shi et al. 2009).

Proceedings of the institute were named *Engineering*, which published over a hundred issues. Content of this magazine covered news about domestic and overseas engineering and construction, transactions and abstracts of related institutes, as well as engineering articles which were chiefly academic understanding of Chinese technical issues, representing the standard of modern Chinese engineering and technology. *Special Issue*, *Special Issue on Engineers' Day*, and *Special Issue for the Conference* were published by the institute as well. Other publications included books such as *American-Chinese Engineering Dictionary*, *A Sketch of Beijing-Zhangjiakou Railway* by Zhan Tianyou, and *Locomotive Series*, all varieties of term books, experiment reports about various building materials, reports on investigation at different places, etc. As will be described next, the key project in China in this period was the Qiantang River Bridge.

Pillar II: Mao Yisheng and Qiantang River Bridge

Qiantang River Bridge is located to the south of the West Lake in Hangzhou City, Zhejiang province, near Liuhe Pagoda. It is the first double-decked bridge for both highway and railway designed and built by Chinese, spanning the south and north of Qiantang River and connecting Shanghai-Hangzhou-Ningbo Highway and

Zhejiang-Jiangxi Railway. It took 3 years and a month to build this bridge from August 8th, 1934 to September 26th, 1937. The bridge facilitated transportation across Qiantang River and made possible the viewing of spectacular scenery together with Liuhe Pagoda to the south of the West Lake Scenic Area.

Dr. Mao Yisheng, a contemporary bridge expert, was the designer and chief director of the construction of the bridge. To accomplish his mission, Mao Yisheng resigned from his teaching position at Peiyang College, coming to Hangzhou as the chief designer and chief engineer of the Qiantang River Bridge. He succeeded in driving piles into the riverbed with the pneumatic caisson method, confounding the predictions of foreigners that "the water is deep and the current is fast, so a bridge can never be built over Qiantang River." Workable as his bridge construction plan was, it cost two million yuan at the time less than the plan proposed by an American bridge expert. Many years later, Mao Yisheng recollected, "ever since I came back to serve the country from abroad in December 1919, the most prominent job I've done during the decades was taking charge of the Qiantang River Bridge Project." Qiantang River Bridge stood as a milestone in the Chinese history of bridge construction and the cradle of Chinese bridge engineers.

Change from Traditional Society to Modern Society (1949–1978): The Period of Independent Development

In the middle of the twentieth century, through Chinese people's persistent striving, China won its independence from foreign invaders. Soon after the foundation of New China (The People's Republic of China), the Communist Party of China (CPC) and the Central People's Government gave priority to the development of science and education. The founding of the Chinese Academy of Science in 1949 marked the beginning of the independent development period of Chinese science and technology. In this period, the major challenges for China were the siege and blockade by Western countries led by the USA and the Soviet Union's withdrawal of its experts from China in July 1960, which led to a rupture in relations between the two countries. The Chinese government pursued the strategy of independence and self-reliance, advocating people to "march toward science" and "learn from all countries." The goal of development for China at the time was to "surpass England and catch up with America," realizing the "Four Modernizations." The implementation of "The First Five-Year Plan" (1953–1957) laid a foundation for the industry of New China, the emergence of the eight industry zones which included the industrial zone of coal and the industrial zone of steel, the 15-year-long "Third Front Construction," the rational distribution of industry across the whole country, and the economic take-off of China.

Zhou Enlai (周恩来) proposed the national objective of modernizing industry, agriculture, communications and transportation, and national defense at the First Plenary Session of the First National People's Congress (NPC) in September 1954. Later, Mao Zedong added the modernization of science and culture. In 1964, at the

First Plenary Session of the Third NPC, Zhou Enlai declared formally that the aim of the national development was the modernization of industry, agriculture, national defense, and science and technology. The emphasis was placed on the development of economy and science and technology.

The year 1956 was a milestone in the history of the development of modern Chinese science and technology because in January of this year, China proclaimed "marching toward science." When Japan and the USA were still hostile to New China, Zhou Enlai advocated "learning from all countries." The first long-term plan, "The Long-Term Plan of Scientific and Technological Development (1956–1967)" (i.e., The Twelve-Year Plan), was worked out to encourage the development of science and technology in China, confirming the important fields and crucial issues of scientific and technological development, such as semiconductor technology, computer technology, automation technology, radio technology, nuclear technology, and jet technology. With the joint effort of scientists, engineers, and the support of the entire nation, the general framework of scientific and technological system took shape, which promoted the emergence and development of a series of new industries and sectors of industries. After "The Long-Term Plan of Scientific and Technological Development from 1956 to 1967" was accomplished, five years ahead of schedule, the government formulated the policy of scientific and technological work. The basic task of scientific research institutions was to "make achievements and cultivate talents," and "The Plan of Scientific and Technological Development from 1963 to 1972" concentrated on the implementation of key scientific research projects and technological projects, making important breakthroughs in the fields of nuclear technology, missile technology, and space technology using China's own technical systems and effort.

With sound policies and concrete enforcement measures, China followed the guideline of "developing key areas and catching up with others" in its scientific and technological work. In extremely unfavorable conditions, China made the following surprising scientific and technological developments—in 1958, the first Chinese vacuum tube computer was developed and the first sounding rocket was launched; in 1959, the semiconductor diode and crystal triode were manufactured in China; 1964 saw the first explosion of atomic bomb in China; in 1965, a transistor computer was made and integrated circuits were developed in China; and 1967 saw the first explosion of a hydrogen bomb in China. These scientific achievements, indicating that China had caught up with the world's advanced level in certain scientific areas in a short period of time, enormously enhanced China's position in the world and exerted a widespread and profound influence on the development of science and technology in China. As Deng Xiaoping (邓小平) concluded,

> China must develop high technology by itself, so as to have a place in the world in the field of high technology. If China had neither exploded the atomic bomb or the hydrogen bomb, nor launched satellites since the 1960s, it could not become an influential great power, or be in such a leading position in the world. These embody the capability of a nation, and the prosperity of a nation, a country.
>
> (Deng 1993, p. 279).

Pillar III: Li Siguang (李四光) Refuted Foreigners' Assertion of "China Oil Deficiency"

Since the Second Industrial Revolution in the second half of the nineteenth century, oil, lifeblood of industry, became one of the most important energy sources. In the early twentieth century, Western countries sent experts and scholars to prospect mineral resources in China. During the First World War, a drilling team sent by American Standard Oil Company drilled seven wells in northern Shaanxi, where they believed oil might be found, but with no success. Foreigners from other countries also looked for oil everywhere in China and left empty-handed. They drew the conclusion that China was oil poor.

With large-scale economic construction, New China encountered oil shortages. There were only a few small oil wells at the time, the annual output being 120,000 tons. So 80–90% of the oil needed by the country was imported. By the end of 1953, Mao Zedong and Zhou Enlai invited Li Siguang to Zhongnanhai, inquiring "What do you think of the saying 'China is oil-poor'? If China was really short in oil, should we produce synthesized oil?" Early in the 1930s, Li Siguang had predicted that the subsiding belts of the Neocathaysian Tectonic System in eastern China abounded with oil resources. In response to the question, he explained the geological conditions in China, making it clear that oil would be stored in the subsiding belts of the Neocathaysian Tectonic System. Mao Zedong and Zhou Enlai were convinced by his argument, so they organized large-scale explorations in the Song-Liao Plain and the North China Plain. In less than 10 years, large oil fields such as Daqing Oil Fields and North China Oil Fields were discovered. Hence, China got rid of its oil-poor reputation, which effectively proved the theory of geomechanics originated by Li Siguang. In 1964, Premier Zhou Enlai noted in the Report on the Work of the Government, "Daqing Oil Fields were discovered on the basis of the geology theory of petroleum initiated by a geologist of our own country."

For 60 years, generation after generation of excellent geologists, represented by Li Siguang, were proud of "working diligently in spite of difficulties to exploit mineral deposits, devoted to geological careers." Their exploration work made China a great power with regard to mineral resources. In 1949, the reserves of only two minerals and 300 mines were known, while today 171 minerals are found in China, with over 20,000 mines proving the extent of mineral reserves. Reserves of lead, zinc, tungsten, tin, antimony, rare earths, magnesite, gypsum, graphite, and barite rank first in the world. The total amount and reserves of mineral resources rank the top in the world, while the total amount of the mineral resources exploited ranks second. At present, 90% of the nonrenewable energy sources, over 80% of industrial raw materials, 70% of agricultural production materials, and over 30% of water used for both industry and household come from mineral resources. There are some 10,000 mine enterprises of large or middle scale and over 110,000 small-scaled ones. Over 300 mining cities sprung up in China, including the cities of Daqing, Panzhihua, Pingdingshan, Jinchang, Baiyin, and Jiayuguan.

Pillar IV: "Two Bombs and One Satellite"

"Two Bombs and One Satellite" originally referred to the atomic bomb, guided missile, and man-made satellite and later included both the atomic bomb and the hydrogen bomb. On October 16th, 1964, the first atomic bomb was successfully exploded in Luobupo, China and on June 17th, 1967, the first hydrogen bomb. The first man-made satellite was launched on April 24th, 1970. "Two Bombs and One Satellite" was perhaps the most significant technological achievement of the Chinese nation in the second half of the twentieth century. The terminology actually represents, generally speaking, nuclear technology and space technology developed by China, instead of representing any specific bombs and satellite.

After the foundation of the PRC, pressured by the force of nuclear weapons, China made *The Long-Term Plan of Scientific and Technological Development from 1956 to 1967* initiated by Zhou Enlai, Chen Yi (陈毅), Li Fuchun (李富春), and Nie Rongzhen (聂荣臻) in 1956. Mao Zedong declared in 1958 that, "We must develop man-made satellites," and "It is absolutely possible for us to make atomic bombs, hydrogen bombs and intercontinental missiles in ten years." In spite of the poor and arduous technical conditions in China at the time, many engineers and scientists dedicated their careers to the development of these technologies.

When China celebrated the 50th anniversary of its founding in 1999, the Central Committee of the CPC and the State Council awarded "Two Bombs and One Satellite" medals to 23 outstanding scientists for their contributions to the program. In his speech at the commendation meeting, Jiang Zemin (江泽民) advocated the "Two Bombs and One Satellite" spirit, which is "loving the motherland and contributing selflessly; being independent and self-reliant and striving strenuously; cooperating and progressing" (Jiang 2001, p. 166).

Change from Traditional Society to Modern Society (1949–1978): Continued

Before New China (1949) was founded, there were no more than 50,000 scientists and engineers, among whom less than 500 were engaged in scientific research in over 30 scientific research institutions throughout the country. Scientific research conducted at the time was chiefly concerned with classification of the natural conditions and characteristics of resources in China. Industrial production technology was underdeveloped, while agriculture production basically remained unchanged from several thousand years ago. Modern science and technology was almost nonexistent in every dimension of society. Since the foundation of New China, the country cultivated a group of 9.6 million scientists and engineers, among whom approximately 700,000 achieved a senior title. An integrated scientific and technological research system was established, with over 5,000 independent scientific research institutions and another 5,000 scientific research institutions affiliated to enterprises, colleges, and universities (Hong 2009, p. 285).

In general, the founding leaders of CPC, led by Mao Zedong, worked hard to explore the ways of developing socialist science and technology and education that conformed to the situation in the country. They not only developed the preliminary ideological system of socialist strategies and policies of scientific and technological development, but also succeeded in carrying out socialist education, thus, establishing a socialist education system. In the 17 years soon after the foundation of New China, science and technology and education were developed quickly and tremendously, but since the late 1950s, due to the disturbance of "left" thought, the development of science and technology and education was seriously impeded by political movements. During the "Cultural Revolution," the "left" went to its extreme, so the development of science and technology and education was severely disrupted; many scientists, engineers, and educators were persecuted, which not only damaged economic construction but also hindered scientific development. This is forever a historical tragedy (Hong 2009, p. 275).

Considering the scale, money invested, and labor consumed, the most influential projects in this period included Qinghai-Tibet Highway, Wuhan Changjiang River Bridge, Nanjing Changjiang River Bridge, Guizhou-Guangxi Railway, Chengdu-Kunming Railway, and Baoji-Chengdu Railway.

Change from Traditional Society to Modern Society (1978–2011): The Period of Reform and Opening Up

The major challenges for China in this period were the blockade of high technology by Western countries and the large gap between China and the developed and newly industrialized countries in terms of the accumulation of science and the level of technology. China was weak in innovative capacity, lacking in core technologies, and thus needed to "catch up" to other countries in this respect. To respond, China employed the strategy of "invigorating the country through science, technology, and education"—determined to construct an innovative country.

In more than 60 years since New China was founded, China has grown from a large agricultural country into a mainly industrial one. Led by two significant projects, "Two Bombs and One Satellite" and "Shenzhou VII," China made a historical breakthrough into some highly sophisticated technological areas such as manned space flight, large carrier rockets, lunar exploration, satellite, and navigation.

The most significant projects in China during this period are Qinghai-Tibet Railway, Beijing-Jiulong Railway, West-East Gas Transmission, West-East Electricity Transmission, North-South Coal Transport, Three Gorges Key Water Control Project, Xiaolangdi Key Water Control Project, South-North Water Transfer, Linhuaigang Flood Control Project, Gezhouba Key Water Control Project, Longyangxia Hydraulic Power Plant, Qinshan Nuclear Power Plant, Qinling Tunnel, Hangzhou Bay Bridge, and Beijing-Shanghai Express Railway.

Since China reformed and opened up, there have been four events in the development of engineering, technology, and the cultivation of talent. These are the foundation of the Chinese Academy of Engineering, the enforcement of the "invigorating the country through science, technology, and education" strategy, the construction of an innovative country, and "The Education and Training Program of Excellent Engineers" policy implemented by the Ministry of Education of China.

The Foundation of the Chinese Academy of Engineering

Zhang Guangdou (张光斗), Wu Zhonghua (吴仲华), Luo Peilin (罗沛霖), and Shi Changxu (师昌绪), academicians of the Chinese Academy of Science, published an article, "To Accomplish the Four Modernizations We Must Devote Great Efforts to the Development of Engineering, Science and Technology" in *Guangming Daily* on Sep. 17, 1982. According to the scientist Qian Xuesen, the concept of science and technology denoted the three equal parts of natural science, technological science, and engineering technology. On November 12th, 1993, the State Council approved "The Proposition of Founding Chinese Academy of Engineering." Set up in 1994, the Chinese Academy of Engineering represents both the acknowledgement of the achievements in Chinese engineering and the integration of the Chinese engineering circle at the highest level, inspiring and motivating the creative spirit of engineers and technicians. It plays an active role in promoting the development of engineering, increasing the standard of engineering technology, and enhancing the capability of research, design, construction, and operation. In stating the reasons for the establishment of the Chinese Academy of Engineering, Jiang Zemin stated:

> Engineers are important creators of new productivity, as well as explorers of emerging industries. It is the inevitable requests of accelerating economic construction and social development to respect the creative works of engineers, and to cultivate large numbers of engineers, scientists and technicians.
>
> (Jiang 2001, p. 226)

Implementation of "Invigorating the Country Through Science, Technology, and Education"

"Invigorating the country through science, technology, and education" is a development strategy put forward by the Central Committee of the CPC and the State Council. The strategy is in accordance with "Deng Xiaoping theory" and in line with the basic policies of the CPC. The strategy is based on scientific analysis and a summary of the trend and experience of economic, social, scientific, and technological development of the world in modern times. It takes into consideration the situation in China and estimates the significant effect of future scientific and technological development. This includes the effect of the development of high technology on comprehensive state power, social and economic structures, people's lifestyles, and modernization process. The strategy aims at accomplishing the ambitious goal of socialist modernization construction.

To "invigorate the country through science, technology, and education" is to put Deng Xiaoping's theory of "science and technology as primary productive force" into full practice, sticking to the principle of education as the foundation for change. It gives science, technology, and education the same importance as economic and social development, encouraging the enhancement of the ability to convert the nation's scientific and technological strength into bottom-line productivity. The objective is to improve the scientific, technological, and cultural quality of the entire nation, to develop the economy on the basis of scientific and technological advancement, and the improvement of laborers' quality to accelerate the growth of overall prosperity of the country. Within "The Central Committee of CPC and the State Council's Resolution of Accelerating Scientific and Technological Advancement" issued on May 6, 1995, the national implementation of "invigorating the country through science, technology, and education" strategy was proclaimed for the first time. At the Fifth Plenum of the 14th CPC Central Committee held the same year, the implementation of the strategy was adopted in the compendium for "The Ninth Five-Year Plan of National Science and Technology Development and Target until 2010" as one of the significant guiding principles of accelerating socialist modernization construction in China in the following 15 years or until the twenty-first century. At the Fourth Plenary Session of the Eighth National People's Congress, when "The Ninth Five-Year Plan of National Science and Technology Development and Target until 2010" was proclaimed, "invigorating the country through science, technology, and education" became a basic state policy of China. According to the statistics from the Ministry of Science and Technology of the PRC, the gross domestic expenditure on research and development increased from 40.45 billion yuan (0.6% of GDP) in 1996 to 89.6 billion yuan (1% of GDP) in 2000, while the total number of professionals including engineers, scientific researchers, and teachers increased from 19.92 million in 1996 to 21.65 million in 2000 (The Ministry of Science and Technology of the PRC 2001).

Pillar V: Three Gorges Key Water Control Project

Mr. Sun Zhongshan (孙中山) envisioned "The Three Gorges Project" as early as 1919 in referring to the improvement of the upper reaches of the Changjiang River in *The Constructive Scheme for the Country II Projects* (also known as *The International Development of China*). In 1932, the Construction Committee of the national government sent a hydroelectric survey team to prospect and take measurements for 2 months in the Three Gorges area, drafting building plans for weir projects in Gezhouba and Huanglingmiao. This was China's first survey and design aimed at exploring waterpower resources of the Three Gorges. In 1944, the United States Bureau of Reclamation's chief design engineer, John L. Savage, surveyed the area and drew up a dam proposal for the "Yangtze River Project." In early 1950, Changjiang

Water Resources Commission of the State Council was founded in Wuhan. Since 1955, led by the Central Committee of CPC, related departments made concerted efforts to work on planning for the Changjiang River basin, including prospecting, researching, designing, and demonstrating the “Three Gorges Project.” On Apr. 3rd, 1992, at the Fifth Plenary Session of the Seventh National People’s Congress, “The Resolution to Construct the Three Gorges Project on the Changjiang River” was approved. On Dec. 14, 1994, the construction formally started.

The Three Gorges Project is the largest hydroelectric project ever built in the world. It is located in Sandouping of Yichang, Hubei province, in the middle of Xilingxia, 38 km from Gezhouba Key Water Control Project in the lower reaches. The project includes the construction of main buildings and drainage works. With the investment of ¥ 95.46 billion, it took more than 11 years to construct the project from Dec. 14, 1994 to May 20, 2006.

The merits mainly include flood control, electric power generation, and shipping. The project benefits the environment, aquaculture, and the project of South-North Water Transfer. The major problems encountered during the construction included cultural relics and historic sites protection, ecological protection, and large-scale displacement of local people.

The drawbacks of the project include issues of national security, as it may become a target for military attacks. Also, rubbish washed from the riverbanks into the reservoir may seriously pollute the water and imperil the drinking water in lower reaches. Besides, high water level when retaining water may cause geological calamity such as earthquakes, landslides, rockfall, mudflow, and so on (Yin et al. 2007).

The Construction of an Innovative Country

On January 9th, 2006, Hu Jintao (胡锦涛), President of China, declared at the National Science and Technology Conference that the objective of scientific and technological development in China in the forthcoming 15 years was to turn China into an innovative country by 2020, making scientific and technological development an effective support to economic and social development. The decision of the Central Committee of the CPC and the State Council to increase overall innovative capacity is a significant strategic decision concerning the general situation of socialist modernization construction. The core mechanism for improving China’s indigenous innovation capacity is to further the enhancement of independent creative ability as the basis of scientific and technological development, moving forward along the road of independent innovation with Chinese characteristics and promoting the development of science and technology.

The core also lies in establishing independent creative ability as the key to industrial structure adjustments and growth pattern transformations, constructing a resource-saving and environmentally friendly society, so as to propel national economic development. To establish China as an innovative country means to strengthen independent creative ability as a national policy to be carried through in every perspective of modernization construction. This in turn will inspire a national spirit of innovation, cultivate advanced innovators, develop systems that encourage independent innovation, and promote innovation of theories, regulations, science, and technology, all toward further consolidating and developing socialism with Chinese characteristics.

Implementation of "The Education and Training Program of Excellent Engineers"

The series of national development strategies put forward by the Central Committee of the CPC and the State Council, such as moving forward along the road of new industrialization with Chinese characteristics, constructing an innovative country, and constructing a strong nation of talent, set a higher demand on Chinese engineering education. To make progress requires a large number of skilled engineers suitable and supportive of industrial development. To construct an innovative country and increase the innovative capability of Chinese engineers, scientists, and technicians demand a large number of innovative engineering talents. To enhance comprehensive national strength and meet the challenge of economic globalization demand an increasingly internationally competitive talent pool of engineers. Therefore, in implementing "The National Outline for Medium and Long-Term Educational Reform and Development," the Ministry of Education of China initiated, in June 2010, a key reform project titled, "The Education and Training Program of Excellent Engineers."

Expected to be carried out from 2010 to 2020, this project aims at gearing education to industry, to the world, and to the future, cultivating large numbers of qualified engineering talents of various types who are highly innovative and could meet the broad needs of economic and social development. Statistics in the June 24th, 2010 issue of *China Education Daily* suggest that 1,000 universities in China offer engineering programs to undergraduates now, which account for 90% of all universities qualified to award bachelor's degrees. It is also shown that the numbers of undergraduates and postgraduates majoring in higher engineering education reached 3.71 million and 470,000, respectively, while the number of engineers, scientists, and technicians reached some 14 million, which means China is now a great nation for engineering education. However, developed from a weak basis, Chinese engineering education is deficient in innovation and practicality, which has always hindered the reform and development of higher engineering education in China.

Focusing on the core issue of engineering capability, "The Education and Training Program of Excellent Engineers" will reform every aspect of the talent-cultivating mode. In educating undergraduates, universities should reinforce the capability of engineering practice, engineering design, and engineering innovation on the basis of general knowledge of science and culture. They should, on the one hand, reconstruct the curriculum system and the content of courses, advocating the research learning method, and, on the other hand, intensify the training of students' innovative capacity and cultivate interdisciplinary talents. When engineers study as trainees, companies should teach new talent advanced technologies and the corporate culture, promoting engineering practices and encouraging them to integrate their graduate projects with technical innovations and engineering development of the enterprises. In addition, they should train students in vocational techniques, professional attitudes, and ethics, while, at the same time, focus more on guiding college students' mental growth with a socialist core value system, giving them effective guidance in developing rational ideas and beliefs. "The Education and Training Program of Excellent Engineers" is characterized by (1) a profound involvement of industries and companies in fostering talent, (2) the cultivation of engineering talents in accordance with prevailing standards and industry standards, and (3) strengthening of students' engineering and innovative capabilities. There are five enforcement measures: (1) construct the new system of university-enterprise cocultivation, (2) reform talent training modes with a stress on strengthening engineering and innovative capability, (3) reform and perfect the engagement system and evaluation system for engineering educators, (4) open engineering education more widely, and (5) the educational and the industrial circles should join the effort to develop the cultivation standard of talents.

Conclusion

The process of scientific and technological development in China demonstrates how China gradually became a powerful nation in science and technology. This has been exemplified by the four phases of scientific and technological development: (1) "learning from foreigners to compete with foreigners" in the Westernization Movement, (2) "marching toward science and technology" in early years of the PRC, (3) "science and technology as primary productive force" in the initial period of the reform, and (4) "invigorating the country through science, technology, and education" from being self-reliant and hardworking to independent research, development, and innovation after importing and assimilating advanced technology from other countries. All in all, in some sixty years after the founding of the PRC, China, with its independent innovation and re-creation of technology learned from developed countries, experienced the development that took other countries several hundred years working "orient miracles." The modern Chinese engineering society accomplished great projects one after another, including the railway running across "roof of the world"—Qinghai-Tibet Plateau, the bridge spanning "Zhujiang Delta," Beijing-Jiulong Railway that runs through southern and northern China, and the Three Gorges Project that "makes a vast lake in narrow gorges."

China has been making outstanding achievements every decade. By the end of the year 2001, supported by and with the participation of academicians of both Chinese academy of Engineering and Chinese Academy of Science, China Association for Science and Technology, and the State Council, Chinese Academy of Engineering screened 25 greatest engineering and technological achievements in Twentieth-Century China (see Table 4.2.).

Table 4.2 Greatest engineering and technological achievements in the twentieth century in China

No.	Achievements
1	Two Bombs and One Satellite
2	Chinese character information processing and revolution of printing
3	Petroleum
4	Crop-yield-increasing technology
5	Prevention and control of infectious diseases
6	Electrification
7	Large river management and development
8	Railway
9	Ship engineering
10	Steel
11	Birth control
12	Telecommunication engineering
13	Geological prospecting and resource exploit
14	Technology of livestock and poultry farming, aquaculture
15	Radio and TV broadcasting
16	Computer
17	Highway
18	Mechanization—major complete-set technical equipment
19	Aeronautical engineering
20	Inorganic chemistry
21	Diagnosis and therapy of surgery
22	Rare metals and advanced materials
23	Urbanization
24	Light industry and textile technology
25	Coal mining engineering

However, in general, through its process of industrialization and modernization, China is still at the primary stage of socialism, lagging behind the most globally advanced countries in a majority of important engineering fields. After some 60 years, China has developed a large-scale national economic system, an integrated industrial system, and a scientific and technological research and development system more advanced than any other developing nation. In the 30 years since reform and opening up, China has made considerable progress in establishing a socialist market economy; building extensive relations in economy, trade, and science and technology with many countries in the world; and accumulating rich experience in internal development with advanced technologies, management, and capital imported from other countries.

By 2011, China has developed an ever-increasing group of 100 million engineers, scientists, and technicians. As Jiang Zemin once pointed out, "Innovation is the soul of a nation, the inexhaustible driving force of a country's prosperity." The Chinese engineering community should and will promote innovation in the new century, dedicated to the industrialization and modernization of China.

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Chapter 5
"Ecocity China": An Ethos Under Development

Erich W. Schienke

Abstract In China, the ecocity has become the model for sustainable urban development. When considering that upward of 45% of the population of China may still urbanize within the next 50 years, the issue of developing China's cities in a sustainable way concerns not only China, it also concerns the world. This chapter first looks at the concept of the ecocity and how it has taken on its own brand identity within China, labeled here as "Ecocity China." Drawing from various examples, an analysis of "Ecocity China" follows as to how differences in constructing ecocity indicators and urban master plans reflect distinctly different ontological and epistemological approaches to sustainable development. Different than most top-down approaches to ecocity design in China, this chapter looks at a promising example of an incremental ongoing "policy by design" approach to ecocity planning and development. Also emerging from this analysis is the realization that to fully embrace ecocity development requires the adoption of eco-cosmopolitanism ethics by governing institutions. Conclusions from this analysis suggest that moving to a robust ecocity approach will be challenging for status quo Chinese politics and that such planning will necessitate a more experimental approach to urban development and establishment of an information infrastructure and a culture of collaborative communication.

Keywords Ecocity • Sustainable city • Urbanization • Development • Sustainability ethics • China • Eco-cosmopolitan

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Introduction

In the year 2000, 50% of the global population lived in cities. By 2025, city dwellers are projected to reach five billion in number across the world, representing over 60% of the world's population. In countries such as China, India, and Brazil, rural to urban migration is happening at an unprecedented rate in human history. This urbanization is presenting rapidly developing societies with technological, material, logistical/planning, health care, infrastructural, and organizational challenges never before encountered on this geopolitical scale. Globally, urbanization is one of the most pressing issues facing both developed and developing societies. To address these challenges at a local level, urbanization requires that the planning, design, and production of cities be brought into a certain coherent organization that is both livable and sustainable. "Ecocity"—short for ecological city—has become the model term for developing just such a livable and sustainable city. However, no successful urban-sized example of an ecocity yet exists in either a developed or developing economic context.

The concept of the ecocity emerged from various urban social movements concerned with improving living conditions for all residents while decreasing the overall ecological footprint of the city toward a zero-sum outcome, that is, from low to no impact.[1] The basis for the ecological city finds its formalization in the works of Paulo Soleri (1973), Richard Register (1987, 2006), Wang Rusong (Wang 2001; Wang and Ye 2004), and Timothy Beatley (2000). While Register does not explicitly provide a steadfast definition for ecocities, he defines *ecocitiology* as "the science and art of investigating, describing, designing, and building healthy cities" (Register 2006, p. 23). In other words, the ecocity is an ongoing process of design and redesign, including municipal policy.

The explicit definitions of what constitute an ecocity are based on qualitative terms and quantitative indicators that have, as of yet, no explicit preexisting examples of systemic success in contemporary urban development. Nevertheless, explicit ecological indicators are being developed based on directives and development imperatives mainly defined by states. (See following section on description of indicators.) These imperatives are articulated in ways that capture public imagination as well as providing the rhetorical framework for setting developmental goals. For example, President Hu Jintao describes the overall goals of China's development as being that of achieving a *harmonious society*—an encompassing metaphor toward which the development of objective standards and indicators needs to be aimed.[2]

[1] Ecological footprints are a way to try to measure the impact of humans on ecosystems, as a means to understand whether an ecosystem can sustain the output needed by a local or global population.

[2] "A harmonious society advocates an overall, coordinated, and sustainable development concept, making the interests of different sectors balanced. So long as we follow this scientific development concept, we can get rid of social unrest and the destruction of natural resources that generally occurs in developing nations. During this period, we should pay attention to the relationship between humanity and nature, properly protect natural resources, reduce pollution, and make efforts to raise the quality of the environment in order to realize sustainable development (China Daily 2005)."

As a means for articulating the goals of the Chinese state, metaphorical phrases such as *harmonious society* and *sustainable development* indicate a set of state values that are to be interpreted as the ends of a development project, such *as the Beijing Green Olympics*, the theme of the 2010 Shanghai World's Fair "Better City, Better Life," or the planned *Dongtan Ecocity* sector of Shanghai. The construction of ecological indicators as objective benchmarks toward these goals is situated in the state's ethos of what happiness and stability mean for the Chinese people. If we consider this ethos within the Confucian philosophical traditions of state, one may even trace to *the Analects of Confucius* and *the Mencius*, theories in support of state performance of the terms of social happiness. That is, the ongoing interpretation of the ethos (*harmonious society* or *ecocity*) is how the state works toward achieving (operationalizing) the virtue of happiness (or "well-offness") for its society. Developing and redesigning China's urban centers need to be conducted in a manner that provides a sustainable economic foundation, enhances surrounding ecosystems, and supports healthy communities. Using example cases, this chapter looks at how interpretations of Chinese ecocities embody an ethos for China's overall sustainable development[3]—even if there is much to be critical of and there has yet to be a definitive and/or sustainable example of success.

Ecocity China

Chinese cities, by many accounts,[4] have some of the world's most polluted conditions—conditions that make readily apparent the need for clean urban development and the implementation of efficient and coherent planning. The degradation problem is compounded when taking into account the fact that much of China's urbanization (rural to urban migration) is yet to come.[5] Because building better cities holds the key to China's urbanized future and economy, the ecocity needs to become a steadfast reality and not just an attempt by regional and local officials to appease the mandates of the central government.

[3] The major challenges to sustainable development in China include the country's rapid economic growth, primarily fueled by the massive consumption of natural resources; China's population and internal growth of consumption; interregional differences between economic and infrastructural development (such as between poorer western provinces and wealthier coastal provinces); and a coherent legal system which can quickly process and uphold necessary laws (State Environmental Protection Administration 2004).

[4] There are multiple ways to describe pollution, but in terms of air pollution and overall water quality, Chinese cities rank among the world's worst. For example, according to a World Bank report, China has 20 cities ranked in the top 30 in terms of air pollution, due mainly to the burning of coal and rapid growth in personal automobile use (World Bank 2011).

[5] In 2009, the percentage of the population urbanized was 46.1% in China, while it was 82% in the United States, 29.7% in India, and 86.1% in Brazil (United Nations Department of Economic and Population Division Social Affairs 2009). As much as another 40% of the population in China and India will urbanize by the end of the twenty-first century, so the already large cities will continue to grow.

The structure of urbanization in China is undergoing rapid transformations. Large-scale land-use changes, increases in material consumption of energy and goods, emissions and climatic effects, and profound shifts in culture are all emerging from the pressure to develop and urbanize the population. Questions concerning ecological sustainability revolve around the success of China's urban centers to control and manage these transformations. The size of China's population means that any significant increase in consumer (consumption) habits is going to impact profoundly on the stock of natural resources, such as forestry products and ecosystem services, and it is urbanization which is the major driver of this increase in consumption.[6]

Urbanization is the primary engine for economic change within China. Migrant workers travel from their home regions in search of construction labor among the thousands of ongoing building projects. Urban centers, particularly since China's economic reforms of the late 1970s, are the primary sectors of industrial, economic, and capital production for both regions and the nation as a whole (Schienke 2006).

Comprehensive approaches to ecocity development in China require thinking beyond the city limits by taking broader regional efforts into the planning process. The relatively recent emergence of the circular economy (CE) approach to urban-ecosystem-economy integration is an attempt to address such questions of material and energy flows across industrial sectors within a specific urban region. These demands have brought about the need for new analytical forms which can encompass multiple types of complexities and transform information about processes from one system (e.g., industrial performance) to another (e.g., watershed management).

> Circular economy is a kind of networking and adaptive ecological economy operated according to the principles of ecological economics of "totality, co-evolution, recycling, and self-reliance," having high efficiency of resource use, and harmonious with surrounding life-support ecosystem. Recycling here means not only material recycling, but, and maybe most importantly, renewable energy use; information feedback; regional symbiosis; efficient monetary circulation; and intelligent evolution of the economic systems itself, towards sustainable models.
>
> (Wang and Liu 2005)

Based on Wang's description of what is required to support a circular economy, it is readily apparent that to actually implement such an approach requires significant coordination of logistics, information, expertise, and material flows across an urban area. Further, circular economy requires coordination across various urban centers within a given region.

Projects bearing the "ecocity" moniker in China range from the planning of multiple cities within a region, an entirely new city, a well-defined sector of a city,

[6] "The number of China's households grew almost three times as fast as its population during 1985–2000, because average household size decreased from 4.5 to 3.5 people. This alone gave China an extra 80 million households in 2000, more than the total number of households in Russia and Canada combined.... China is also becoming more urban. From 1952 to 2003, while its total population "merely" doubled, its proportionate urban population tripled from 13 to 39%. Hence, the urban population increased sevenfold to more than half a billion. The number of cities increased fourfold to more than 660 (including more than 170 with at least one million residents), and the areas of existing cities grew significantly" (Liu and Diamond 2005).

a newly expanding sector of a city yet to be built, the redevelopment of a currently industrial city, an aspect of urban master planning of current cities, or as a dimension of urban infrastructure such as transportation and energy. In addition to a general overall focus on net impacts, ecocity projects further vary in how the designs take into account impacts on and use of local ecosystems and biodiversity. As much as it is a definitive approach to development, the concept of "Ecocity China" has also become a brand and, as such, is often subject to interpretation by marketing interests. While initially promising, entire unfulfilled ecocity projects such as Dongtan (at the mouth of the Yangtze River on the outskirts of Shanghai) have received harsh critiques from, among others, the Ethical Corporation, which referred to Dongtan Ecocity (Castle 2008) as a "masterpiece of greenwashing on several accounts" (French 2007). The main problem with the Dongtan Ecocity project appears to arise from the fact that local (Shanghai) interests were represented by land developers (probably hoping to turn estuary into highly valuable land) working in conjunction with foreign design experts. The result was a heavily designed project without any governmental or public support worthy of note.

The concepts underlying ecocity planning, however, are too fundamental to overall sustainability to be ignored. Moving forward, urban and regional planning, and questions concerning overall development, will necessarily require following an ecocity plan in one form or another. Further, if China is to move past its dominant "factory to the world" model for ensuring sustained economic growth, policy makers will need to more seriously consider how to best leverage ecocity principles such as regional circular economics, zero-emissions transportation, renewable energy, and biodiversity. It is crucial, however, that further false starts such as Dongtan do not tarnish the "Ecocity China" brand. Rather, "Ecocity China" needs to become an ethos for the overall development of China. Cities are key to the economies that drive contemporary civilizations. Ecocities, then, are key to China's future ecological-economic conditions that will drive future *ecological civilizations*, a concept that is only beginning to be used. If indigenous terms of success are realized, "Ecocity China" will become a very viable and attractive brand of ethos for most of the developing/redeveloping world.

Ecocity Indicators: The Epistemology and Ontology of Ecocities

Before analyzing examples of ecocities projects, it is useful to understand how ecocity projects are typically measured. Ecological indicators—usually included in broader formal urban master plans—are used to measure how well an ecocity is performing (achieving its "ecocity-ness"). Ecocity projects also require attention to the design of indicators themselves. There are common indicators that are found in a variety of projects, and there are green building standards such as the US LEED building standards,[7] but there exists no set standard for indicators or measures for

[7] Leadership in Energy and Environmental Design (LEED) is a green building certification system developed by the US Green Building Council in 2000 (U.S. Green Building Council 2011).

an entire city. Zero-net greenhouse gas emissions are a likely standard most ecocities would consider as a major benchmark, but this alone does not take into account the other dimensions under consideration, such as biodiversity, commuting distances, richness of social interactions, and other factors that make a city livable. Nevertheless, ecocity projects require indicators by which their successes can be measured. Overall, the argument here is that ecocities are (ontologically) determined by indicators more than by a prescribed set of sociotechnical arrangements.

To understand how indicators differ across projects, consider the key performance indicators (KPIs) for the Sino-Singapore Tianjin Eco-City project (launched in 2009) and compare these with indicators developed for the Caofeidian "Genetic City" project as proposed by the Dynamic City Foundation (DCF). The purpose is to demonstrate that different approaches to indicators are possible (and useful) mainly because they attempt to measure ecocity as a constructive "ethos" as opposed to ecocity as a definitive benchmark. Some of the indicators are significantly qualitative in character and represent more a sense for how people ought to behave and act within an ecocity and the *ends* toward which ecocities ought to be striving.

Both Tables 5.1 and 5.2 represent "ontological sets" of an ecocity. That is, the indicators within these tables delineate the categories and imperatives that signify and comprise "ecocity-ness" in the minds of planners, architects, policy makers, etc. Referring to Table 5.1, the Sino-Singapore Tianjin Eco-city (SSTE) project, the categories (left column) represent the *ends* toward which the indicators are targeted. For example, good lifestyle habits, developing a dynamic and efficient economy, and balance in the man-made environment more resemble categories of happiness and could be easily found alongside indicators of gross national happiness (GNH) rather than alongside indicators of economic development, such as gross domestic product (GDP). The key indicators (right column) were developed "to guide [Tianjin Eco-city's] planning and development into a model city for sustainable development" (Singapore Ministry of National Development 2008). The key indicators, thus, are intended to represent model ecocity goals and are the highest standards of either country. "In formulating these KPIs, reference is made to national standards in China and Singapore, and the higher of the two standards is adopted wherever feasible" (Singapore Ministry of National Development 2008).

In comparison, Table 5.2, representing the Caofeidian (CFD) "Genetic City" project, prescribes a more functional or physiological approach to analyzing the ecocity. First, the CFD approach breaks down the analysis according to functional systems within the city (which is more similar to the Richard Register approach) and then sorts the indicators into functional categories within the system. It should be noted that the CFD approach is not comprehensive of the overall proposal or project and that there are other significant aspects to the proposal that take into account social dynamics. Further, there are many subcategories of architectural specifications. The CFD approach to ecocity indicators keeps focus on functional systems that can be engineered, while the SSTE approach includes social ends and human "talent" ratios that can be planned for, but not guaranteed through engineering alone. (The CFD approach locates these considerations elsewhere in its design plans.) For example, in calling for "at least 50 R&D scientists and engineers per

Table 5.1 Key performance indicators (KPIs) for the Sino-Singapore Tainjin Eco-City Project (SSTE)

Category	Indicator
Good natural environment	Ambient air quality: The air quality in the ecocity should meet at least China's National Ambient Air Quality Grade II Standard for at least 310 days. The SO_2 and NOX content in the ambient air should not exceed the limits stipulated for China's National Ambient Air Quality Grade 1 Standard for at least 155 days
	Quality of water bodies within the ecocity: Water bodies in the ecocity should meet grade IV of China's latest national standards by 2020
	Quality of water from taps: Water from all taps should be potable
	Noise pollution levels: Noise levels must fully comply with China's standards for environmental noise in urban areas
	Carbon emission per unit GDP: The carbon emission per unit GDP in the ecocity should not exceed 150 tonne-C per US$1 million
	Net loss of natural wetlands: There should be no net loss of natural wetlands in the ecocity
Healthy balance in the man-made environment	Proportion of green buildings: All buildings in the ecocity should meet green building standards
	Native vegetation index: At least 70% of the plant varieties in the ecocity should be native plants/vegetation
	Per capita public green space: The public green space should be at least 12 m^2 per person by 2013
Good lifestyle habits	Per capita daily water consumption: The daily water consumption per day each person should not exceed 120 l by 2013
	Per capita daily domestic waste generation: The amount of domestic waste generated by each person should not exceed 0.8 kg by 2013
	Proportion of green trips: At least 90% of trips within the ecocity should be in the form of green trips by 2020. Green trips refer to nonmotorized transport, i.e., cycling and walking, as well as trips on public transport
	Overall recycling rate: At least 60% of total waste should be recycled by 2013
	Access to free recreational and sports amenities: All residential areas in the ecocity should have access to free recreational and sports amenities within a walking distance of 500 m by 2013
	Waste treatment: All hazardous and domestic waste in the ecocity should be rendered nontoxic through treatment
	Barrier-free accessibility: The ecocity should have 100% barrier-free access
	Service network coverage: The entire ecocity will have access to key infrastructure services, such as recycled water, gas, broadband, electricity, and heating by 2013
	Proportion of affordable public housing: At least 20% of housing in the ecocity will be in the form of subsidized public housing by 2013
Developing a dynamic and efficient economy	Usage of renewable energy: The proportion of energy utilized in the ecocity which will be in the form of renewable energy, such as solar and geothermal energy, should be at least 20% by 2020

(continued)

Table 5.1 (contiuned)

Category	Indicator
	Usage of water from nontraditional sources: At least 50% of the ecocity's water supply will be from nontraditional sources such as desalination and recycled water by 2020
	Proportion of R&D scientists and engineers in the ecocity workforce: There should be at least 50 R&D scientists and engineers per 10,000 workforce in the ecocity by 2020
	Employment-housing equilibrium index: At least 50% of the employable residents in the ecocity should be employed in the ecocity by 2013
Qualitative KPIs	Maintain a safe and healthy ecology through green consumption and low-carbon operations
	Adopt innovative policies that will promote regional collaboration and improve the environment of the surrounding regions
	Give prominence to the river estuarine culture to preserve history and cultural heritage and manifest its uniqueness
	Complement the development of recycling industries and promote the orderly development of the surrounding regions

Source: (Singapore Ministry of National Development 2008)

10,000 workforce in the ecocity by 2020," the SSTE approach heavily emphasizes the need to enhance local innovation capacity in science and technology, an issue tied directly into China's overall medium-term indigenous innovation goals. (See China's 15-year Medium-to-Long Term Plan for Science and Technology (2006–2020) (Cao et al. 2006)).

There are significant similarities between the two approaches, but there are some critical differences as well. Both sets of indicators from the SSTE and CFD projects seem viable approaches to setting the design goals and constraints toward ecocity ends. Both approaches propose quantitative benchmarks for ecocity development.

The SSTE approach uses current and projected government standards whenever possible, which is not surprising considering the project is primarily collaboration between governmental organizations and actors. What we can understand from this is that the ecocity itself is a venue for political collaboration and interchange of discourse and goals about development between East-Asian regional partners. The discussion is as much about shared development values as it is about what an ecocity ought to be. The deep involvement of local and national officials in the SSTE project appears to result in the overt attention given to discussing the social and environmental ends of the ecocity project, to the point that the somewhat vaguely worded ends provide for the overall categorization of indicators. This approach, however, makes it difficult to arrive at a sense for whether the 26 key indicators are enough to satisfy or justify the ends they are categorized under. Difficulty also occurs in parsing differences between the categories and their underlying indicators. For example, when evaluating "good natural environment" versus "healthy balance in the man-made environment," many of the indicators are able to

Table 5.2 Ecocity system analysis for Caofeidian "Genetic City" proposal

System	Classification	Identifier
Compact city system	Housing	Percentage of total housing that is economically affordable and low rent
		Housing mixture of different rent forms and property right based on different price levels and areas
		Per capita land for construction projects
		Per capita residential area
		Housing footprint ratio to number of inhabitants
		Per capita housing footprint
	Public service facilities' accessibility	Green spaces and public parks ratio to public buildings
		Investment ratio of per capita public construction funding
Green architecture system	Construction environment	Set database of every single building eco-technology, building construction, and other contents for monitoring and management
		Eliminate harmful materials: Follow a list of harmful and toxic materials
		Indoor air quality: radon density
		Indoor air quality: good ventilation
		Indoor air quality: The nitrides content of interior space meets with the national standard
		Indoor noise environment quality fit national standards
		Indoor daylighting physical environment quality: fit national standards, using ecological technology to achieve a comfortable temperature, humidity, and good physical environment
	Green construction	Use a set of inspection standards and environmental management system (ISO 14000, LEED, etc.)
		according to the national standard or make appropriate method to of environmental report and grading
Green Transportation system	Transportation efficiency	Time difference between taking public transportation and cars from major residences to main workspace journey with less than 1.5 times difference between taking bicycle vs. cars from major residences to main workspace journey
	Transportation mode	Walk and nonmotorized traffic-sharing rate
		Bus-sharing rate
		The ratio of green commuting

(continued)

Table 5.2 (contiuned)

System	Classification	Identifier
	Transport energy efficiency	CO_2 emissions caused by traffic
		The percentage of renewable energy sources in traffic energy consumption accounts for total energy demand
		The percentage of traffic energy consumption accounts for whole city energy consumption
		The rate of gas-based of public transportation and taxi
Solid waste recycling system	Solid waste collection	Frequency and rate of waste recycling
	sanitation infrastructure	"Coverage scale of waste transport vehicles of transportation closed"
Water recycling system	Supply and demand	The pass rates of drinking water
	Recapture for reuse	Permeable surfaces
	Enhancing groundwater	Ecological treatments and processes
Ecological environment and public space system	Coastal defense	Erosion protection
		Tsunami protection
	Forestation rates	Afforestation coverage in the city
		Urban buildup green land rate
		Per capita public green land area
		Per capita park green land area
	Atmosphere and air quality	Days which better or equal to "level two" air quality standards and
		days which better or equal to "level one" air quality standards of:
		NOX emissions
		SOX emissions
		CO emissions
		Noise emissions
	Water quality	The reclaimed water quality reaches the urban wastewater standard
	Ecosystem quality	Biodiversity rates
		Biocomplexity rates

Source: Preliminary materials from the "Genetic City" Caofeidian project (Dynamic City Foundation 2010) fit under either category. Overall, the SSTE approach seems to consider the ecocity itself as a means to the categorical ends of state development.

In comparison, the CFD design proposed by an architectural group working under the direction of the Dynamic City Foundation exemplifies an architectural design approach to ecocity planning and benchmarking. The engineered design and management of urban systems, then, become the way to achieve the functional ecocity itself, which is an ongoing (genetic/genealogical) process of adaptations. If an ecocity is the *ends* of the CFD project, then designing management indicators for these urban systems is necessarily the primary *means* toward those *ends*.

The categorical choice of indicators, in both examples, is representative of the overall ontology of the ecocity plan in question. The indicators represent the (epistemic) knowledge that is to be collected to determine whether the plans for implementation are on the expected course. The primary differences between these two examples appear to be at the ontological level, where governmental actors produce and perform an ecocity ontology that conforms with overall state development goals, whereas the design actors produce an ecocity ontology that conforms to the broader design community’s approaches to ecocity planning.

Ecocity Urban Master Planning

Urban master planning is a common and essential tool for the midterm (5–15 years) and long-term (20–50 years) development planning of an urban region. Ecological and engineering performance indicators, described above, are a significant component of overall urban master plans. Urban master planning, as verb, refers to development and planning for various dimensions of an entire urban region, ranging from block-by-block neighborhood planning to regional resource management. As opposed to other development plans for a city, urban master planning refers to the overall land-use and infrastructural plans. Urban master plans, as objects of decision making, are the diagrams, models, and policies that result in a 5- to 50-year plan for how land-use and transportation networks, for example, will be allowed to change. Urban master planning is not specific to any political system, though it is seen applied much more in planned geographic-economic situations, such as in China, the former Soviet Union, or in Germany under the National Socialists. Urban master planning is more prevalent in political systems where there is a planned economy and the government exercises strong powers of eminent domain.

Within compatible political systems, some form of urban master planning is an essential tool for enabling the comprehensive oversight necessary to the short- and long-term implementation of ecocities. Issues such as reduction of urban sprawl, efficient transportation, energy infrastructure, building efficiency, urban heat island effects (Xiao et al. 2008), and ecosystem services cannot be addressed without a properly complex and coherent master plan. Developing ecocities based only on existing regulations is currently not sufficient to ensure green development, let alone ecocity development. This is particularly the case in China, since upward of 30% of new residential construction around urban areas such as Beijing are unapproved by the state and municipal governments but are typically "approved" by well-connected local officials (Schienke 2006). Comprehensive master planning coupled with proper and sufficient implementation of local regulations appears to be *the* necessary political baseline for implementation of a functional ecocity in China. Anything less would likely result in an ineffective outcome, contributing further to social, economic, and ecological problems extending from rapid urbanization.

Based on ongoing ethnographic investigations (since 2004) into Chinese ecological development (Schienke 2006, pp. 146–231), the biggest challenges ecocity architects and planners face is not at the level of technology or engineering capacity, but at the level of local political capacity to implement proper rule-of-law within the existing base of inflexible building codes and regulations. While architects and planners can produce what appear (in models, at least) to be viable ecocities, they often encounter significant hurdles with local regulations that are not compatible with eco-efficient designs. For example, a common regulation is that buildings are required to have a specific offset distance from roads and from other buildings, with sufficient pedestrian space and some viable green space. This essentially results in a medium- or high-rise building that gets located squarely in the center of the lot. Considering impacts only at the scale of the building, this regulation does not seem unreasonable. However, at the scale of the city block and of city sectors, this regulation prevents the efficient use and connection of pedestrian and transport space, green space, and mixed-use space—all of which are essential to the well-functioning ecocity. Even if one sector of the city is planning to be ecocity-scaped, such as in Tianjin or Shanghai, the rigid building regulations typically apply citywide. Thus the ecocity encounters debilitating regulatory hurdles before it even gets started. The reasonable response, then, seems to be to allow for the flexible design of the policies and regulations that are needed to achieve the necessary ecocity designs, which is the procedural inverse of the typical master planning processes. This "policy by design" was precisely the approach proposed by the Dynamic City Foundation (DCF) in their "Genetic City" CFD exhibit at the World Expo 2010 Shanghai (Dynamic City Foundation 2010). This is explored in the next section.

Ecocity Policy by Design: "Genetic City" Caofeidian

> The second hurdle for sustainability involves regulations. Urban planning codes have not yet been updated to deal with the broad implications of contemporary forms of urban sustainability. In previous research it became clear that in China, working within the official planning regulations effectively makes it impossible to design a sustainable city. Apart from inadvertently promoting sprawl, the regulations actually prevent innovation. The building off-set rules produce cities that are hostile to pedestrians. As a result, although green buildings and technologies are welcomed and often good planning is attempted, the city is unable to break away from inefficiency, congestion and pollution.
>
> (Mars 2011)

Over the long term, an in-depth comparative analysis of different approaches to ecocity plans in China will help render a detailed picture of the range of policy recommendations that are necessary to produce regulations compatible to ecocity development. For now, the example of DCF's "Genetic City" provides useful examples and lessons learned when considering underlying policies and regulations as part of the design process.

The case discussed here focuses on the outcomes, first displayed at the World Expo 2010 Shanghai, of a collaboration between ten Dutch and Chinese architectural/urban design teams working collaboratively on sequentially evolving an ecocity design for Caofeidian—currently an industrial-converted economic development zone in Bohai Bay under the jurisdiction of Tangshan City, Hebei Province—which is projected to grow from 100,000 inhabitants in 2010 to 1,000,000 inhabitants in 2040. Results from this collaboration indicated that following an "ecocity ethos" could result in vibrant designs but that these designs cannot be implemented without similar and necessary reforms in building codes and development policies for these particular regions.

The experimental development of a longer-term approach to comprehensive green master planning for Caofeidian Eco-city puts its designers at the center of many diverse and interconnected challenges of development in China. The Caofeidian Genetic City project collected ten different design teams, Chinese and Dutch, to contribute to an evolving 30-year master plan for CFD from 2010 to 2040. In an iterative relay format for the design process, each team began with the conditions set by the previous team and a set of projected technological, social, political, ecological, and economic constraints. Each team expanded upon previous teams' designs to create a quickly "evolving" (genetic) set of plans and possible trajectories, all toward the ends of a livable and realizable ecocity. The result and output is an imbricated set of 3-year plans, one by each different team, each posing a relatively new image of a rapidly developing Chinese city, similar to numerous other locations throughout China.

Findings that emerged from this collaborative design process can be categorized in three significant ways. First, urban policy and planning processes should be flexible in the near term and stable in the long term to be able to adapt to unforeseen conditions and take advantage of new technologies. Second, major policy incentives, such as "special ecological zones," should be developed to strongly encourage developers/builders to take advantage of ecologically focused strategies. Third, sociocultural, economic, political, technological, and ecological contingencies should be considered in relation to each other, that is, one contingency cannot be deterministically anticipated to result in benefits to other sectors. For example, technological adoptions, while perhaps efficient, do not determine cultural continuity/harmony as a result.

Findings[8] from the "Genetic City" experimental design suggest that (1) China's urban planning processes need to be much more flexible in contexts where change is occurring rapidly and the goal is *ecological civilization*; (2) any contingency can

[8] These findings are drawn from personal field notes and direct participation with the Dynamic City Foundation leading up to the launch of "Genetic City."

be a driver of most any other and, from both the design and planning perspective, need to be anticipated to the best capacity possible; (3) without significant (and already existing) benchmarks on the road to a successful ecocity strategy, attention will need to be given to forms of valuation (signifiers) other than market performance, that is, ecosystem services, measurements of happiness, etc.; and (4) the properly developed ecocity can mediate between major interests and become an incubator for the rest of China's ecological aspirations. Overall, China needs to experiment further with the design of urban policy itself.

Toward Eco-Cosmopolitanism as Ecocity Ethics

We live in an increasingly crowded world where cultures are in close and continuous contact and where individual actions can have consequences at a distance. As Anthony Appiah points out, these days, mostly anyone exiting an international airport or walking through a city will encounter more people in one day than our ancestors encountered in their entire lifetime and that these conditions require us to be increasingly *cosmopolitan* (Appiah 2006) in how we approach our ethical obligations to others. Cosmopolitanism, referring to *citizen(ship) of the world/cosmos,* is a branch of ethical theory addressing questions concerning responsibilities, obligations, affinities, and loyalties to all humans, regardless of national, regional, or local affiliations. Approaches to cosmopolitan ethics can vary widely depending on the degree to which duties to local individuals are considered more obligatory over duties to a global population and the moral, political, cultural, and economic context of the duty or obligation under consideration. Recently, scholars such as Ulrich Beck, Patrick Hayden, and Ursula Heise have presented environmental approaches to cosmopolitanism that discuss individual duties and obligations which are demanded in response to global environmental and ecological risks. Cosmopolitanism in climate change obligations has been evaluated in depth by Paul Harris (2011) and in Schienke's analysis of China's ethical obligations to address climate change across scales of governance (Schienke 2011). Articulations of *cosmopolitics* and narratives of risk and science are also developed by Isabelle Stengers (2010) and Bruno Latour (2004). Further, Jacques Derrida (2001) analyzes cosmopolitanism with respect to "cities of refuge," which provides an interesting analog if one considers that which is seeking refuge to be the ecosystem itself. All of these considerations, from environmental risk to duties and obligations, play out to some level in concepts underpinning the Chinese ecocity. President Hu Jintao's notion of a *harmonious society* can even be considered a call for a kind of Chinese cosmopolitanism.

The Chinese *ecocity*, if properly implemented, would take the need to remain vigilant about protecting ecosystems and environment out of the overt responsibility of each and every resident and make living an ecologically sustainable lifestyle a product of the structural constraints and opportunities of the urban design. The structural principles underlying ecocity design link local considerations of urban development to regional, provincial, national, and global interests. Incorporating the ecosystem as a fundamental aspect of the urban system requires the consideration of impacts not only at the scale of governmental institutions but to the scales of ecosystems as well, that is, linked to habitats of particular species, but also linked to larger systems such as the regional ocean ecosystem and the global climate system. In other words, linking urban development to ecological protection and enhancement innately requires the consideration of impacts in nonlocal cosmopolitan terms or what Heise (2008) refers to as an "eco-cosmopolitanism." Further, eco-cosmopolitanism seems to be an ethical system intrinsic to the very concept of ecocity. For example, *circular economy* could be considered a form of economic and material cosmopolitanism, where local considerations and obligations are linked into a broader regional and even global industrial production cycle.

The implementation of proposed special ecological zones in China to support robust ecocity and circular economy implementations would necessarily link local policy and planning considerations to regional, provincial, and national decision-making processes. Ecocities, then, will further necessitate a form of political eco-cosmopolitanism among collaborating political actors and organizations, which may encounter certain significant barriers in a top-down bureaucratic China (Schienke 2006). However, ecocity development may also provide an opportunity for further collaboration between civic and regional authorities. In addition to comprehensive communication across organizations, another significant dimension to a well-functioning ecocity appears to be the processes and infrastructure for robust sharing of information and federation of data about all dimensions of the urban system. As well, a moral eco-cosmopolitanism will require the protection of the ecosystems within which the city is woven. Further, a shift toward a more eco-cosmopolitan culture within ecocities will necessitate an increasingly open position on information sharing not just about ecosystems but also about other eco-cosmopolitan cultures throughout the developing and redeveloping world.

For China to embrace the ecocity as something more than a traditionally planned city with a few green-washed enhancements, the status quo will also need to reflect eco-cosmopolitan ethics. Current trends in the politics of information sharing and attitudes toward critical reflection needed for a successful ecocity implementation indicate that a transition to an eco-cosmopolitan society would not come easily for China.

Conclusions

The "Ecocity China" brand is continuing to find purchase in China's rapidly urbanizing society, a brand that will continue to grow in relevance and import, as 40–45% of the nation's population still needs to urbanize if it is on course to reach the level of most OECD countries. Considering any dimension of socioeconomic analysis, questions concerning China's urbanization are key to achieving sustainable development, both for the nation and globally. The ecological planning of cities, in addition to the explicit design of ecocities, will influence China's future significantly. The ontological approaches to categorizing ecocity indicators and the epistemological approaches to measuring ecocity effectiveness have both practical and ethical implications. As demonstrated here, one approach to ecocity planning can reflect the need to maintain political ethos of the state while another approach reflects the functional needs of the ecosystem in which the city is embedded. Paying close attention to how elements such as indicators are chosen or constructed is important, as differing ecocity-planning approaches can have significantly different epistemological and ethical outcomes.

As an overall ethos for China's development, "Ecocity China" seems worthy of close attention in how it continues to be constructed. Such an ethos will face push-back in significant arenas that China may find contentious to its *status quo*, in that a successful ecocity will necessarily need to embrace some form of eco-cosmopolitanism. Further enhancements in collaboration between local, regional, provincial, and national authorities will also prove a logistical and political necessity, such as in the implementation of a regional circular economy that supports the material flows in and out of centers of industrial production. Improved federation of ecological and economic data will also prove necessary, as will improving capacity for unfettered communications between individuals, institutions, industry, and planners. Finally, China will need to embrace more of an experimental approach to planning and development, much in the way it did when Deng Xiaoping opened up the special economic zones following the social and economic reforms of 1978–1979. Opening up areas as special ecological zones that allow for necessary and incremental changes to construction policies will also become a necessity. In sum, "Ecocity China" is an ethos that requires continual interpretation, reflection, and experimentation, as it could be the key to China's common and sustainable future.

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Chapter 6
Negotiated Development: Rediscovering a Global Development Ethic

Peter McEvoy, Jane Grimson, and William Grimson

Abstract This chapter explores an approach to international development programming as a negotiated process, rather than one which is either imposed or contested. The authors posit this 'negotiated' development paradigm as one which aligns well with key features of good development practice as currently understood (such as responsiveness to needs, local ownership of projects, participatory planning and a focus on sustainability), as well as with the recent and growing emphasis among international donors on aid effectiveness and focus on results. Side by side with this, the contribution of higher education to international development is also discussed in some detail, and attention drawn to its potential to underpin the negotiated development approach with a firm evidence base.

Keywords Development • Negotiated • Education • Higher education

Introduction: How We Got Here: Learning from 40 Years of Faltering Effort to Eliminate World Poverty

The international development aid challenge – to reduce world poverty and to ensure food and water security and dignity of all – is at once both simple and complex to grasp. A simple stark reality is that over the past 25 years, global food

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production has grown more rapidly than global population, but yet more people than ever before now live in hunger and poverty. According to the World Food Programme (www.wfp.org/1billion):

- One person in six goes hungry each day.
- One child dies every 6 seconds from hunger and the diseases it causes – that is, five million children each year.
- Every year throughout the world, almost ten million children die before their fifth birthday.
- Based on current trends, child deaths in Africa alone are set to grow by an additional 700,000 a year.

Where development becomes complex is the fact that where development is concerned, everything is connected to everything else. Water, trade, infrastructure, land, access to capital, debt, nutrition, health, education and respect for human rights are all linked inextricably within a web of interrelated but often independently variable factors, all of which impinge in some way on the quality of life of a given community. In order to gradually enable people to build up their fractured self-esteem, restore some hope and confidence and help to develop their capacity, it is necessary to:

- Generate income in a self-reliant manner.
- Conserve soil from erosion.
- Purify water.
- Offer protection from infection.
- Make the most of whatever nutrition is available.
- Assert their rights as citizens to services from their government.
- Give their children a chance to go to school.

The development process thus comprises many facets and factors. When these are moving forward in concert, a mutually reinforcing virtuous circle will be generated. But if – as so often happens – progress on one front becomes negated and undermined by slippage on others, the spiral instead becomes a downward and often a very vicious one. Although the repercussions of particular development projects cannot always be foreseen, the risks of unwelcome surprises arising during and post-implementation can be significantly reduced by systematic and participative consultation beforehand among stakeholders, and this is the essence of the ‘negotiated development’ concept which we are advocating in this chapter. The negotiated model can be encapsulated in adherence to the three Ps: participation, partnership and pro-poor priority setting; all are necessary preconditions to achieving the necessary sense of buy-in and ownership by beneficiaries which in turn makes for longer-term project sustainability.

The Quest for Good Development Practice

Though the basic interconnectedness between key development factors may appear self-evident and straightforward to grasp, it has tended to elude policy-makers for decades past, whether at the level of national governments in the global south or within the institutional donor agencies responsible for disbursing development aid. More recently, a more holistic approach to understanding development practice has been gaining ground and has found expression in internationally agreed frameworks for development involving all the key official development partners, in the form of the Paris Declaration 2005 and the Accra Agenda for Action 2008 (OECD 2008). Key components of this framework are (a) harmonisation of aid effort across the traditional sectoral demarcations, (b) alignment of development partner programmes with national policy frameworks and (c) managing for development results. Tangible results are about positive improvements in the lives of poor people.

But looking back over the past 40 years, it is surely surprising that it has taken so long to institutionalise this axiom of development as a holistic process. A stylised characterisation of the evolving development discourse and practice over the past four decades would reveal that we have taken a circuitous route to reach where we now are, lurching from one fixation to another, eventually forging the general consensus about 'integrated development' encapsulated in the Millennium Development Goals (MDGs); http://www.un.org/millenniumgoals/bkgd.shtml.

In the post-colonial 1960s, the 'holy grail' in development terms was thought to reside in economic growth reaching a 'take-off' point: economic growth was defined by Simon Kuznets, winner of the Nobel Prize in Economics in 1971, as 'a long-term rise in capacity to supply increasingly diverse economic goods to the [country's] population, this growing capacity based on advancing technology and the institutional and ideological adjustments it demands' (Todaro 1989); what emerges here is a technocratic, fairly unidimensional definition of the perceived key to progress, devoid of any real recognition of distributional equity, social cohesion, the nurturing of a participative and active 'civil society' and the 'common good'. This was also the era of massive infrastructural projects (Upper Volta, Kariba and Cabora Bassa dams) and of efforts towards rapid industrialisation (relying heavily on parastatals as the key engines).

During the early 1970s, significant themes embraced in development thinking were (a) the 'green revolution', epitomised by 'miracle' high-yielding rice and other crop varieties which were supposed to revolutionise agricultural yields and thereby eliminate hunger, and (b) a focus on disease prevention and eradication through mass vaccination (smallpox, yellow fever, typhoid, etc.).

During the 1980s, the development policy became pervaded by neoliberal macroeconomic strictures and 'structural adjustment' programmes, resulting in an aggravated debt crisis which continued into the successive decades.

The 1990s saw the spotlight being put on interrelated issues such as gender equity, population control, reproductive health and combating the prevalence of HIV and AIDS, along with a significant focus on universal basic education (e.g. the seminal 'Education for All' 1990 conference in Jomtien, Thailand). More recently, gender roles have been explored in the context of water politics and the dynamics of how activists fought their battles in 'water wars' in Bolivia (Laurie 2011).

The development landscape of the past decade has been dominated by the MDGs with their implied recognition that the fight for poverty reduction had to embrace all sectors of development interventions, plus climate change and debt relief. There was a growing appetite in the international community for more joined-up thinking and concerted action. Although the MDGs were backed up by commitments on donor cooperation towards aid effectiveness in Paris in 2005 and Accra in 2008, translating these protocols into operational effect has proved to be challenging.

What May Go Wrong If Development Is Not Negotiated?

At the heart of our concept of negotiated development lies the maxim that the development process should be primarily people centred. Technical and logistical issues of programme design should therefore be approached first and foremost from the starting point of clarity about which needs – and perhaps more importantly, *whose* needs – are to be addressed. What also needs to be assessed carefully is the potential ‘collateral damage’ to livelihoods and social conditions of people having to live with the consequences of misguided project planning. A case study is presented in this section of the chapter of a major infrastructural project that went wrong. Some salutary lessons about the importance of ‘negotiated development’ can be drawn from this instance where the converse happened.

The Tana River project is not unfortunately an isolated example. The World Bank’s report, ‘Resettlement and Development – The Bank-wide ‘Review of Projects Involving Involuntary Resettlement 1986–1993’, concludes that violations of its own resettlement policy were common in many of its projects involving forced relocation. The World Commission on Dams (WCD) undertook a wide-ranging meta-study of the impact of major schemes for construction of dams and associated hydroelectric schemes, with particular reference to developing countries (WCD 2000). Their finding was that the initial assessments of such projects consistently underestimated the number of people who were either displaced from their domicile or whose livelihoods were adversely affected in the long term by, for example, irreversible changes in the water table levels, soil conditions or access to markets. Examples of major dam projects in Africa where such difficulties were experienced included the tri-national Ruzizi hydroelectric project (serving DRC, Rwanda and Burundi), the Funtua dam in Nigeria and the Kiambere reservoir scheme on the Tana River in eastern Kenya. According to the comprehensive survey of all major dam projects carried out by WCD, it was found that 35% more people were displaced and had to be resettled than originally planned. This tendency towards underestimation of negative impact was even more pronounced in the case of schemes funded by the World Bank, where the actual number of involuntarily resettled people turned out to be 47% higher than the estimate made at the time of initial project appraisal.

Kenya's Tana and Athi Rivers Development Authority (TARDA): A Case Study

The 300-mile long Tana River – the longest in Kenya – was harnessed in the 1980s by two major projects: the Kiambere hydroelectric dam scheme and (some 240 miles downstream from it) the Bura irrigation project. Both were co-funded by the World Bank. The text that follows is adapted from 'Troubled Waters: World Bank Disasters Along Kenya's Tana River' (Horta 1994).

The Kiambere Dam

This major infrastructural scheme was designed to create 140 MW of electric power. But little attention was paid at the planning stage to the fate of the people who once farmed the fertile valley and were forced to leave when the reservoir was filled. A social survey of the affected area was carried out only when construction was nearly complete, by which time some 6,000 people were already displaced (six times the original estimate). In the absence of a resettlement plan, people lost their land, access to water and pasture for their cattle. Threatened by hunger, many found refuge in surrounding villages, thereby increasing pressure on the livelihoods of communities that absorbed the displaced population.

The Bura Irrigation Project

Downstream from the Kiambere dam, the Bura irrigation project was supposed to irrigate about 35,000 acres to grow cotton and maize, at an estimated cost of $98 million. Although the cost rose to $108 million, only about 6,000 acres were actually irrigated, while social measures (including 20 village health units) were cancelled. Some 20,000 farmers from different parts of Kenya were induced to resettle to Bura by the illusory promise of irrigated agricultural land. Instead for them drought and famine made them dependent on food aid from the United Nations World Food Programme. The Bura project area now resembles a ghost town: housing units built for project staff stand empty, dilapidated and looted; huge water towers stand abandoned in the scrubby landscape; and irrigation canals have become overgrown with thorny vegetation. The project has also had an adverse impact on evergreen floodplain forests, which were rich in plant and animal species.

The Bura project has been a drag on the Kenyan economy, as the debt is repayable in hard currency, adding pressure to increase exports to generate foreign exchange.

The World Bank's Project Performance Audit Report in 1990 concluded that project managers should have been alert to the problems at an earlier stage and taken remedial action. The Bank now recognises the defects in appraising past infrastructural projects and has put in place policies and guidelines for stricter social and environmental impact assessments at the outset.

Past instances of deficient practice reflect not so much a failure in terms of technical appraisal of projects, but an insufficient grasp of what integrated development is, and how it can best be given operational effect; this realization is surely key to good development outcomes, requiring negotiation with the different levels of stakeholders affected. In more recent times, the track record in major dam schemes (e.g. the Lesotho Highlands Water Project), although still controversial, would suggest that some essential lessons have been learned from painful experiences of the past (See WCD 2000). Independent environmental and social impact assessments are essential, as are advance and meaningful consultation with communities affected by such schemes and proper provision for resettlement plans and development packages, designed to enable displaced communities to regain their productivity and to rebuild a viable and conducive social milieu. Implementation of such a resettlement plan has become part of the contractual obligations between the international financial institution concerned (e.g. World Bank or African Development Bank) and the borrower (typically the national government, public utility or regional development body). Consequently, the World Bank now declines to finance projects entailing population displacement without prior guarantees of resettlement policy standards and formal consultation mechanisms being put in place (Cook 1994).

But the pursuit of integrated development in turn requires the capacity to promote good development practice which is properly informed by independent evidence-based research across the diverse multidisciplinary spectrum of specialist knowledge relevant to development. For example, the Tana River case study points up the need for development practice to encompass both the 'hard' technical expertise (engineering, health, environment, etc.) with insights from 'softer' disciplines key to an effective negotiation process (social sciences, community development, training for transformation, communications, conflict resolution, etc.). Our contention, developed in the next section of this chapter, is that this potential to harness and integrate cross-disciplinary knowledge and research in the service of development can be provided by the higher education (HE) sector and that the two worlds of HE and development therefore need to engage with each other as never before.

Changing Perceptions on Higher Education's Contribution to (Inter-)national Development: A Historical Overview

Higher education (HE) has a vital role to play – alongside government and wider civil society – in promoting human development, in a way which puts peoples' needs first and which has poverty alleviation and poverty eradication as its overarching goal. This is even more true at the present time. As socio-economic development becomes more knowledge intensive, the role of HE is essential to the promotion of balanced and coherent national development strategies of reduced child mortality; eradicating poverty; ensuring democracy, peace and respect for human rights; and striving for environmental sustainability.

Though this may seem self-evident, there have been significant shifts in attitudes towards HE's role over the past 40 years, just as the conventional wisdom on development policy overall was seen to have shifted significantly over that period of time. Following independence, African universities enjoyed a period of growth and national prestige and were perceived as engines of nation building and economic modernisation. Regarded as powerhouses of human capital formation, they were expected to lay the basis for economic take-off. HE was also seen as important to the process of Africanisation, producing the graduates to replace the colonial administration. The private sector was still dominated by ex-colonial multinational corporations (MNCs) with very limited requirement for local graduates, and the colonial legacy continued to influence strongly university-state relations. Thus, the early period of independence was mainly positive for the expanding university sector, which enjoyed the support of several international donors. (For more detailed treatment of this expansionary phase, see Ajayi et al. 1996). However, many of the negative aspects of colonial times remained and state dominance continued. National governments of newly independent states increasingly asserted their rights to 'own' and exert control over HE institutions, one indication of which was the extent to which vice-chancellorships and other senior appointments became politicised.

The development of the concept of human capital in the 1960s led to a literature of detailed analysis of the contribution of education to economic growth and of the costs and benefits of different levels of education. By the mid-1980s, scepticism was growing among international donors about the merits of public investment in HE in less developed countries. For most of two decades, HE institutions were hopelessly overstretched by a combination of dwindling resources and rapidly increasing enrolments. During the economic downturn of the 1980s, the newly independent governments could no longer afford to support universities to a level necessary for standards to be maintained. The situation was exacerbated by Structural Adjustment Programmes and the contraction of the public service, for which many graduates were destined. Large-scale graduate unemployment ensued, causing an exodus of talent (or brain drain). A generation of academic talent was lost, with untold damage done to the human capital base, depleted as it was of specialist skills in key areas such as agronomy, medicine, hydrology, pedagogy, applied statistics, law, public administration, journalism, engineering, business and commerce.

The contribution of HE to economic and social development relative to other priorities became sharply contested. In particular, a World Bank report (1986) analysed the contribution of education to economic growth and of the costs and benefits of different levels of education, using earning differentials as a proxy measure for quantifying direct benefits. This study also presented conclusions based on comparative analyses of rates of return to investment in different levels and types of education across different regions of the world. It also compared the returns to individuals (the private rate of return) with the returns to wider society (the social rate of return).

The conclusions were that the private rate of return (the economic benefit to the individual) was greater than the social rate of return (the economic benefit to society as a whole) for all levels of education. But the greatest social rate of return accrued to primary education, followed by secondary, with third level being the least ‘cost effective’. This analysis, which only subsequently turned out to have been oversimplistic, was used to supporting a public policy stance of preferential investment in primary education. The World Bank report asserted that in most developing countries, ‘the present financing arrangements constitute a misallocation of resources devoted to education’ because ‘HE was the relatively less socially efficient investment’ (World Bank 1986, pp. 9–10).

This finding was widely quoted and exerted considerable influence on the lending policies of the World Bank itself, on domestic priority setting by governments at country level and on the aid strategies of international donors in the two decades that followed. This position was regarded as supporting a public policy of preferential investment in primary education and was reflected in the World Declaration on Education for All (UNESCO 1996). Although this Declaration emphasised the importance of education broadly, it revealed an almost exclusive focus on primary education, further reinforced in Millennium Development Goal 2 of universal primary education by 2015. The argument was further strengthened by the fact that HE was generally confined to the relatively richer urban middle classes who were effectively being subsidised by the rural poor who did not have access to this education, thus increasing inequality.

Higher Education and Development Effectiveness

The unduly arbitrary segmentation of education implicit in this analysis ran counter to the more integrationist view of HE’s role in development which has re-emerged in more recent years (King 2009). The essential interdependence between the different levels of education can be demonstrated very clearly with reference, for example, to MDG 2 – achieving universal primary education. In the final analysis, how can this goal be realised without high-quality teacher education, accompanied by properly moderated state examination systems, a rigorous school inspectorate, reliable management information and other associated infrastructural frameworks, all of which link directly back to the indispensable role of HE as a repository of expertise and builder of capacity for these very functions? The same rationale holds true of the other key sectors of health, water and sanitation and agriculture and food.

An endorsement of this more rounded view of things is discernible in the influential Report of a Task Force on Higher Education (World Bank 2000), which, though commissioned by the World Bank, distanced itself from – and superseded – the earlier orthodoxy of the mid-1980s which this new report said had ‘relegated higher education to a relatively minor place on its development agenda’. The earlier basis of calculating the social rate of return was shown to have been unduly restrictive (relying largely on relative earnings data) and had therefore underestimated the indirect benefits of education to society ('externalities'). But in the meantime, the damage was done*:*

> for the best part of a generation, university faculty salaries remained flat or declined, research funding dried up, university libraries stopped purchasing books and journals, physical facilities crumbled, new building was terminated, … student scholarships were largely eliminated, … and new faculty hiring was curtailed.
>
> (Szanton and Manyika 2008, p. 2)

The onset of the HIV and AIDS pandemic further depleted the human resource base in HE in sub-Saharan Africa.

Squaring the Circle

Teferra and Altbach (2003) suggest that 'the problems [facing Africa's universities] are difficult and may even be getting worse as the pressure for academic and institutional expansion comes into conflict with limited resources'. However, the situation is not considered irretrievable, with the authors pointing to three very positive trends which inspire hope, namely:

- The emergence of democratic political systems in certain countries of sub-Saharan Africa, along with a more vibrant civil society across the continent.
- A revival of collective self-confidence in African HE and the renewed commitment by many to build successful and resilient institutions despite difficult circumstances.
- Recognition by leading donor agencies that investment in African HE is vital for development.

Other trends underline this momentum for change. Presidents are no longer chancellors, and universities are seeing their autonomy strengthened albeit in return for greater transparency, equity of access, economic relevance and accountability. 'Buffer' bodies are being introduced in the form of national councils for HE which help mediate relations between the HE sector and the state. In keeping with the neoliberal ethos, the state is being 'rolled back' and universities are being encouraged to diversify their funding sources reducing dependence on the state, fees are being introduced and student services are being privatised. Furthermore, a rapidly growing private HE sector is emerging in several countries. The exclusive focus on primary education is being questioned, and recent World Bank reports (World Bank 2000, 2002) have emphasised the role which universities can and should play in poverty reduction. Earlier rate of return calculations based on potential earnings has been challenged (World Bank 2000, p. 39; Bloom et al. 2006). While confirming the earlier view that the private benefits of university education include better employment prospects, higher salaries and a greater ability to save and invest, recent research provides much better evidence of the social or public rates of return. These include at the very least the role of universities in the education of teachers, doctors and other professionals essential to economic development. Externalities and spillovers to society include better health, lower birth rate, improved technology and strengthening of governance and democracy (Bloom et al. 2006). Thus, a much stronger case for investment in universities and HE generally is being established and is being given a further boost by the increasing emphasis on the development of knowledge-based economies to which universities are central.

The role of the state has changed from one of financial neglect to one of renewed interest and even active support. Civil society has found its voice and is contributing to the emerging public debate on the development of HE. With increasing decentralisation of government, local community groups are competing with each other to attract new universities to their area on the basis that they benefit the local community, economically and socially.

However, it is in the private sector where the biggest changes are to be seen. Private universities are an increasingly important feature of the educational landscape ranging from the world class Ivy League universities of the USA to the small for-profit unlicensed – and often unscrupulous – operators. The private sector's role is no longer confined to that of prospective employer of graduates but increasingly as a provider of educational services which can be traded on international markets. In keeping with the neoliberal agenda, this opens up the educational market to global competition, rolls back the state, eliminates the monopoly traditionally enjoyed by the state-funded national universities and allows the individual student to enter the market and make choices in order to maximise private gain for themselves. In theory, it also offers opportunities for the sub-Saharan Africa (SSA) university sector to create strategic partnerships and to gain access to global markets. However, given the current state of the public university sector in SSA, this opening up of markets threatens to undermine them even further especially in the absence of appropriate legislation to control the market, ensure quality and protect citizens from rogue operators selling degrees and qualifications across the internet.

From the analysis presented above, it is apparent that the respective roles of the state, the civil society and the private sector in the development of the university sector in SSA are contested, evolving and negotiated in an increasingly competitive global market. Appropriate public policy and actions do not divide neatly into the threefold categorisation of steering, enabling and contesting development but rather have elements of all three. The question is therefore whether and to what extent there is any convergence in relation to public policy between the neoliberals (associated with enabling immanent development) and the interventionists (associated with steering development) and those who contest development orthodoxy (people-centred development). Where there is consensus around policy and action, it is often for completely different reasons.

Firstly, there is broad agreement that a strong university sector has an important role to play in economic growth and hence in poverty reduction (World Bank 2000, 2002; Bloom et al. 2006). For neoliberals, the sector is primarily valued for its direct contribution to economic development, whereas others would also include its contribution to the development of civil society and democracy.

Secondly, there is fairly general agreement that universities should be given greater autonomy and independence from government, but in return they must be accountable and relevant. Neoliberals seek to empower the HE sector (public and private) to compete in the marketplace, whereas those supporting people-centred development (and many interventionists) are motivated more by the social imperative to protect academic freedom and an education system based on merit.

Thirdly, there is a high degree of consensus in relation to local partnerships and community participation in HE. All agree that the location of a university in a particular area benefits the local economy directly in terms of providing jobs, in supporting local industry and also in potential spin-off activities from university research. Neoliberals see this as an opportunity for both cost sharing and stimulating economic growth. Interventionists and people-centred development proponents also emphasise the social and educational benefits to the local community.

Fourthly, it is accepted that the state must intervene to regulate the educational market especially as the demand for university places greatly exceeds the supply available through the public sector. Unregulated 'universities' offering degrees for sale over the internet undermine the university sector as a whole bringing qualifications into disrepute and breeding mistrust among potential employers.

The state has a critical role in developing a comprehensive policy framework that considers both public and private institutions, multiple entry paths and credit transfers or, as the neoliberals would put it, creating an enabling regulatory environment easing entry into the marketplace and offering appropriate financial incentives (World Bank 2002, p. 83).

Fifthly, the imperative to improve both the quality and quantity of third-level education in SSA is widely acknowledged. While most people accept that chronic underfunding is largely to blame for poor quality, many neoliberals also attribute the problem to inefficiency, poor governance and corruption by the universities themselves.

But the issue of where expansion in the sector should take place – in the public or private sector, in specific disciplines or across all areas – is less clear. The state and the private sector have a preference for private sector growth, whereas many sections of civil society would prefer to see the expansion taking place in the less commercially oriented public sector and in the faith-based not-for-profit sector.

Even more controversial is whether increasing student numbers should be spread across all disciplines or confined to specific disciplines. Neoliberals and some interventionists feel that state investment in universities in SSA should be targeted principally at those disciplines which will yield the greatest economic benefit, namely, science, engineering and technology (SET). Given the high cost of teaching these subjects, it is highly improbable that the private sector will address any supply-demand imbalance. Other interventionists and certainly those supporting people-centred development would be more likely to favour increases across all disciplines on the basis that diversity is important to providing a rich and stimulating academic environment – and that students should be free to choose.

The area of greatest divergence not surprisingly is who should pay for university education. Neoliberals demand the (re)introduction of fees, together with a student loan system or graduate tax, on the basis of market principles: but this has proved problematic (Teferra and Altbach 2003). For the universities, the ability to charge fees reduces their financial dependence on the state and is also associated with improved student motivation, attendance and completion rates. However, many elements within civil society oppose the introduction of fees, seeing it as inherently inequitable and as effectively paying twice – once through the public taxation system and a second time through the fees.

While tertiary enrolments expressed as the percentage of the age cohort enrolling in postsecondary education vary dramatically from country to country, virtually all the countries with enrolments of less than 5% are in SSA (compared to over 50% in North America) (World Bank 2000, p. 12). If the countries of SSA are to be able to reduce poverty, improve health and participate in the global knowledge economy, then the current enrolment rates must increase significantly – and quickly. This will require a hitherto unprecedented partnership and consensus between the state, the civil society and the private sector, together with the universities themselves and the major international agencies. As this chapter has shown, even though their motivation may be quite different, there is a growing consensus among the key players. The challenge will be to develop a university system that is 'of Africa for Africa' which take its place in the global university sector while at the same time supporting economic growth and poverty reduction locally.

Some Key Challenges

To be effective, pro-poor policies need to operate across multiple sectors and to do so in an integrated way which promotes alignment, harmonisation and coherence, (c.f. the Paris Declaration 2005 and the Accra Agenda for Action 2008). Coherence between external donor initiatives and those of host government, combined with mutual alignment and complementarities between donor agencies themselves, can help ensure that policies across a range of issues support, or at the very least do not undermine, the attainment of development objectives. '*Put simply, policy coherence is about ensuring that time and effort is not wasted by actions in one sphere, undermining actions in another*' (House of Commons 2004).

Historically, it has proved difficult for policymakers and other stakeholders to identify which policies are most suitable when dealing with national priority issues and to ascertain how best policies can be implemented in situations which differ widely. The most obvious difficulty is that of precisely attributing cause-and-effect. Despite these inherent problems, the ethical imperative of ensuring a better quality of life for the poor, as well as sustaining the planet beyond the crux of 'peak oil', calls for a better understanding of how research in the areas of education and poverty can contribute to pro-poor policies and help improve development outcomes. The sheer scale of global need is such that we cannot afford the luxury of efforts and resources being fragmented. For maximum benefit, more research needs to be focused on the poor. For example, 'at present, only 10% of the global spend on health research examines issues affecting the poorest (90%) of the world's population' (Department for International Development 2009, p.13).

There is increasing interest among both researchers and policymakers in applying this new thinking to the link between development research and development policy. Donors are keenly interested in tracking the longer-term outcomes and impact of development interventions. Both parties are interested in knowing what works and herein lies an opportunity for HE institutions to provide rigorous, evidence-based independent analysis. Many research findings could be more readily available to inform policymakers on poverty prevalence, HIV/AIDS, unemployment, better quality health and education and service delivery, but more often than not, a gap exists between research results and policy development and the desired outcome of converting research results into practical benefits for quality of life. This is of particular concern in terms of the challenge of meeting the MDGs.

We wish to conclude this section by positing some key challenges to be considered in forging a more negotiated approach to development policy and practice.

Awareness Raising: At long last, the penny has begun to drop at high level policy thinking that integrated national development strategies and sector-wide approaches to education must necessarily include the revitalisation of the HE sector. Nevertheless, there remain significant pockets of scepticism about HE's essential role in national development, not least in many Ministries of Finance around Africa. It is known, for example, that the African Development Institute now strongly favours providing funding for strategic development in HE precisely because of its multiplier effect throughout the economy, but this is being thwarted by most national Ministries of Finance. Some echelons of the donor community also remain to be convinced.

Language: Sometimes, the HE sector fails to do justice to its own indispensible contribution to human development, partly because the language of discourse which it tends to use is not fully shared with those who are more directly engaged in policy and practice. Perhaps the description of a research question or hypothesis tends too often to be couched in terms which are accessible to the academic or specialist peer audience, to the exclusion of a more generalist audience who might well be enthused by the potential of a research application to transform livelihoods or to be a catalyst for social change. Perhaps also the mechanisms for disseminating research findings which are of potential importance to development policy and practice need to be broadened beyond the traditional peer-reviewed journals, to include web-based resources and broadcast material.

Promoting Quality Assurance. Enrolments in African HE are rising exponentially, but quality assurance mechanisms are only in their infancy.

Insularity Arising from Economic Uncertainty in the Global North. It is not suggested that HE institutions should somehow reinvent themselves as development agencies or advocacy interest groups. But what is being suggested here is that such is the urgency and scale of the twin challenges of poverty reduction and sustainability of the environment that these:

1. Must become central points of orientation for our institutions.
2. Are mainstreamed into the day-to-day work of teaching, research and civic engagement in country.

3. Act as the 'glue' for strong long-term north-south collaborative partnerships which reflect our growing interdependence – such as the Irish African Partnership (http://www.irishafricanpartnership.ie/).

Bridging the Gap Between Policy and Research. A study on factors promoting and inhibiting development-related research, undertaken by the Irish African Partnership for Research Capacity Building (Healy and Nakabugo 2010), provided a springboard for subsequent dialogue with development practitioners. Some interesting suggestions for 'action points' emerged from this process:

- To help overcome the perception that academic research is removed from the daily reality of most 'ordinary' people, researchers need to ensure that their research connects with real and defined needs in the wider community and that the potential contribution (or 'the big idea') is conveyed in plain language.
- Maximising the interface with the policy environment, researchers need to know how government works, as policy is political rather than academic.
- Researchers benefit from nurturing structured dialogue with user-communities, *via* nongovernmental organisations (NGOs), faith-based organisations, etc. and building in community consultation processes into research methodologies.
- Institutions should be more prepared to accord recognition to staff who demonstrably practise sustained civic engagement.
- Researchers must look for new and effective channels of dissemination, in order to 'get heard', opening up communication to policymakers and partnering with civil society groups.

Conclusion

Negotiated development where it can be said to occur does not happen in a formal space, rather it emerges in a variety of informal and often unstructured ways and at different phases of any proposed development project. While this chapter has focussed to a large extent on sub-Saharan Africa, the lessons learned are not unique to that region. The story of the Misicuni big-dam project in Bolivia illustrated the point where globalisation, neoliberalism and regional interests interacted in sometimes surprising ways to reach a 'settlement' (Laurie and Marvin 1999). The debates around the project centred on a number of issues including cultural understandings of the central nature of the project which involved the reduction and use of water courses. Like many such projects, it was the local inhabitants who were most affected and were essentially, at least initially, the marginalised party.

This chapter underlines the importance of education in a development context. Taking education as an essential prerequisite, it is clear that negotiated development needs local advocates who have been trained to understand the complex interaction between those funding or promoting a development and the many parties involved. Very simply, the most marginalised need a voice if an ethical development is to materialise. And that voice needs to be well rehearsed in all the 'ingredients' that come together when significant development projects are initiated. Equally well others need to be sensitised and trained and be prepared to listen to that voice.

So, two things are required. First, that a cadre of development specialists are educated and trained, ideally in the broad region where they will operate. This is becoming a feature of education in less developed countries. The National University of Rwanda has a Master's programme that 'aims at developing a systematic understanding of the policy process and its application to sustained economic and social development in transitional economies'. And with respect to water (still the single most important challenge in much of the world), the university has initiated a Master's in Water Resources and Environmental Management and that involves in its initial stage a 'training of trainers' programmes by which guest lecturers, supported by UNESCO-IHE, train local staff to subsequently deliver the programme (National University of Rwanda: http://www.nur.ac.rw/spip.php?article30).

Second, trust needs to be to the fore if negotiations leading to development are to be satisfactory. Baroness Onora O'Neill in the Reith 2002 BBC lecture remarked that Confucius told Tsze-Kung that three things are needed for government: weapons, food and trust. If a ruler cannot hold on to all three, he should give up weapons first and food next. Trust should be guarded to the end. Without trust, we cannot stand (O'Neill 2002). It follows then that the second and broad requirement is that donors and donor countries, agencies and local governments have to operate in a manner that leads to and engenders trust. Without question, this means that again education or re-education is the critical factor but this time for the rich nations who wish to support the development.

It should not go unremarked that the profession best placed to being at the centre of negotiated development is engineering. The first reason is that it is engineering that is at the core of so many developments. The second reason is that by virtue of their training and professional obligations engineers must take not only technical matters into consideration but also ethical and societal ones. If engineering has sometimes fallen short of the standards it aspires to, it remains the case that as a profession, through its multiple interactions with all the parties involved, it is one that can lead the way to ethically negotiated development.

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Part II
Rethinking Engineering Education

Introduction

Andrew Jamison and Yi Shen

From the early nineteenth century, when institutions for educating engineers were first established as part of the more general industrial transformation taking place in Europe and America, there have been a number of fundamental tensions as to how that education should best be conducted, what it should consist of, where it should take place, and, not least, who is best suited to do the educating.

On the one hand, there has been a tension between what might be termed different styles of engineering education, between “practice-driven” approaches that have sought to develop teaching methods and curricula that are intended to meet the needs of the future employers of those being educated, as opposed to “theory-driven” approaches that have tried to develop engineering education in ways that uphold the academic values of those doing the educating. Where the one approach has tended to emphasize practical and, more recently, problem-based forms of learning usually with large doses of on-the-job training, the other has tended to emphasize theoretical or science-based learning, and the two approaches have thus served to pull engineering education in different directions, in terms of pedagogical methods, curriculum design, and learning outcomes.

Secondly, in relation to what is to be taught, tensions have developed because of the historical changes in engineering and engineering knowledge themselves. The processes that Joseph Schumpeter so famously referred to as “creative destruction,” as waves, or cycles of technological development have superseded one another over the past 200 years and have had important effects on engineering education. With each of the waves, there has been a change in the kinds of skills and knowledge that have been central to engineering activities. Each wave has been governed by a different kind of “techno-economic paradigm,” based on a particular cluster of technical

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and organizational innovations that have given rise to new branches of industry, new public works and infrastructural projects, and, with them, new fields of engineering. In the nineteenth century, there were tensions between the older fields of civil and mechanical engineering, which were important in the "first wave," and the newer fields of electrical and chemical engineering and thermodynamics, which were important in the second wave.

In the nineteenth century, fields such as aeronautic, automotive, and environmental engineering emerged out of the radical innovations – especially automobiles, airplanes, and industrial chemicals – which were important in the third wave, and, more recently, computer engineering, communications, and information technology, which have been so important in the second half of the nineteenth century. These historical shifts in techno-economic paradigm or cognitive regime have all led to tensions in engineering education about what engineers should learn to know and, not least, to hierarchies and status conflicts among the fields of engineering. The emergence of new fields of techno-science (e.g., biotechnology, nanotechnology, and synthetic biology) provides the most recent manifestation of this cognitive tension.

In terms of where the education is best seen to take place, tensions have arisen over the past two centuries due to the differentiation into three main "contexts" or sites of engineering activity, namely, the economic, or commercial contexts; the social, or national contexts; and the cultural, or community contexts. In each contextual setting, or site, engineering has a different meaning, and identity, which is related to different "story lines" or discourses of technological change, one emphasizing product development and economic innovation, the other emphasizing system-building and social construction, and the third emphasizing community development and cultural appropriation. In relation to engineering education, the different contexts have tended to create their own separate institutions and given rise to different engineering identities.

Finally, in relation to who is best suited to educate engineers, there has been a historical tension between engineers and non-engineers. In the nineteenth century, engineers struggled throughout the industrializing world to gain support for their profession in the broader culture, and in the twentieth century, there developed a gap between what C.P. Snow in 1959 famously termed the "two cultures." In relation to engineering education, this tension between technology and culture has meant that some instruction in nontechnical, social, and cultural subjects has been seen as necessary, but it has always been a conflict or struggle over who should provide that instruction and over the role of contextual knowledge in engineering education.

The chapters in this part discuss these tensions in different ways. In Chap. 7, Ela Krawczyk and Mike Murphy set the stage by depicting three different overarching scenarios for the future and ask how engineers should be educated according to each. Where the first scenario emphasizes the continued importance of a globalizing capitalist world market, the second posits a major transformation toward "a more peaceful, equitable and environmentally sustainable world that maintains relative balance between civic society, governments and business." The third scenario envisions a world that "has been shaped by a socio-political backlash against the forces of change prevailing in 2000s" and, as such, calls for a very different sort of engineer than the other two.

Chapter 9 by Steen Hyldgaard Christensen on academic drift in European professional engineering education provides examples of how the tensions between theory-driven and practice-driven approaches to engineering education have been met historically in Europe. It describes trajectories in which external political events and policy measures have brought about changes in orientation and direction. Christensen points to an interesting paradox in European engineering education; while engineering colleges have drifted in an academic direction, vocational drift has been a dominant trend in universities, making them ever more market-oriented. In some sense, there is a convergence toward a hybrid strategy that combines theoretical instruction, or book learning, with practical instruction, or learning by doing.

The tensions between the forms of education is a central theme in both Anders Buch's Chap. 10 on "governing engineering" and Chap. 11 by Andrew Jamison and Matthias Heymann, which traces the tensions back to the dawning of European civilization. As part of the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED), these two chapters present three contending response strategies to the challenges facing engineering and engineering education. By reviewing a number of recent reports and other documents on engineering education, Buch identifies what he terms a business strategy, a professional strategy, and a hybrid strategy, each of which sees the challenges facing engineering quite differently. He argues that the linkage between the response strategies and the challenges cannot be construed as causal relations. Instead critical attention should be given to the discourses that are used to frame challenge perception. He thus emphasizes the discursive shaping of challenge perception by story lines and metaphors developed in broader historical and social formations. Jamison and Heymann makes a similar point in arguing that these contending response strategies are based on long-standing historical traditions, each with different ideas of engineering and engineering education.

In Chap. 12, Steen Hyldgaard Christensen and Erik Ernø-Kjølhede show how these tensions are very much alive in the contemporary attempts to integrate social or contextual knowledge into engineering education. In a longitudinal case study on the implementation of theory of science carried out at Aarhus University, Institute of Business and Technology, from Spring 2007 to Fall 2010, they look specifically at the process through which instruction in theory of science has been brought into Danish engineering education and, based on interviews with teachers and administrators, bring out the highly contentious nature of these educational reform activities.

Ulrik Jørgensen, in Chap. 13, discusses developments in engineering education since World War II. He argues that the vast increase in US federal funding of engineering research related to what came to be called the military-industrial complex in the wake of World War II and the Cold War period as well as increased government research funding in Europe were decisive factors for a paradigm shift in engineering education. The paradigm shift tilted the balance in engineering curricula toward research disciplines and away from knowledge created in practice domains of engineering. As a result a crisis emerged during the 1980s in relation to engineers' role in manufacturing as well as in design, leading to controversies over the organization of engineering education and how to reinvigorate teaching creativity and engineering design competence. Drawing on recent research in science, technology, and engineering studies, the chapter ends outlining new approaches to teaching engineering and building curricula.

China followed a different trajectory of educating engineers in which the relevance of engineering education to nation building was visibly symbolized. In Chap. 8, Brent Jesiek and Yi Shen examine the institutional history of one of China's leading engineering schools, Shanghai Jiao Tong University (SJTU), from its founding in 1896 through the formation of the People's Republic of China in 1949, with particular emphasis on how the university and its engineering programs evolved in tandem with national development and defense priorities from the late Qing Dynasty through the Nationalist period. Such account contributes to the understanding of the historical foundations and formation of a comprehensive engineering education system in China tailored to build and manage the nation's infrastructure.

In Chap. 14 Gary Downey argues for studying and participating critically in engineering formation through its normativities by which he means linkages to broader socio-material projects. His chapter critically examines *normative holism*, a tendency among engineering leaders to equate technical engineering work and the advancement of humanity as a whole. Drawing on case studies from late nineteenth-century Japan, Germany, and France, Downey shows normative holism to be a variable multiplicity of commitments linked to the trajectories of countries, as engineering educators understand and embrace them. He further argues that engineers' ready embrace of normative holism makes it a key site for effectively translating critical analysis into critical participation. Downey asks: If students and working engineers can begin to see and analyze dominant normativities as such, might they be more able and willing to explore additional and alternative normativities?

In the final Chap. 15 in this part, loyalty and practical morality in Engineering Education are discussed by Martine Buser and Christian Koch. In their study they construe the student's role as a legitimate peripheral participant in engineering practices within a modus 2 context, defined here as a triangular relation between the student, the university supervisor, and the mentor company. Within this context students work on problem-oriented projects and deal with complex decision-making processes and consequently take part in the enactment of practical morality. Having to face the constraints and limits of real-life project development in an organization, the students struggle within a web of technical and technological knowledge; loyalty relations to various actors, norms, and regulations; as well as market demands. These tensions and their related trade-off inherent to quick decision-making leave little space and time to reflect on ethical questions. Nevertheless, Buser and Koch in their study have shown that engineering students within a modus 2 context display a steadily growing ethical awareness during their professional formation.

Chapter 7
The Challenge of Educating Engineers for a Close, Crowded and Creative World

Ela Krawczyk and Mike Murphy

Abstract The world that is emerging based on the development and everyday use of new technologies is a world that can be described as close, crowded and creative. Studies have highlighted that traditional curricula and pedagogical methods for engineering education are deficient in terms of developing and nurturing key skills required by engineers to succeed in this world. The challenge for the engineering academic leaders of today is to begin with the end in mind: to begin with a description of the competences that the engineer of the future should have in order to succeed in their aspirations as an engineer and then to reverse engineer both the curriculum and pedagogical approaches to enable the desired outcome. This chapter describes what is meant by a close, crowded and creative world: the world in which engineering graduates must learn to practise. It then proposes three different possible scenarios for the world of 2030 and discusses the key skills that engineers in 2030 should possess in order to succeed as engineers. This chapter concludes with recommendations on how to address the challenges of educating engineers for a close, crowded and creative world.

Keywords Educating the engineer • Engineering skills and competences • Scenario planning • Engineer 2030 • 'Close, crowded and creative world'

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Tomorrow's World Today

What world are we living in today and what will the world look like that our children will live in tomorrow? In an award-winning book, Thomas Friedman describes the world of today as flat, by which he means that it is a world in which companies operate globally on a level playing field and wherein the development and application of technology shrink both time and distance (Friedman 2006). It is a world in which the continued development and application of technology lead to revolutionary implications for countries, companies and the individual.

The US National Academy of Engineering (NAE) describes guiding principles that it sees as shaping the world in which the engineer will practise in 2020. From the perspective of our world today, these principles are evolutionary and as characterised by Friedman. In the world of 2020:

> the pace of technological innovation will continue to be rapid, the world will be intensely globally interconnected; the population of individuals who are involved with or affected by technology will be increasingly diverse and multidisciplinary; social, cultural, political and economic forces will continue to shape and affect the success of technological innovation; the presence of technology in our everyday lives will be seamless, transparent, and more significant than ever.
>
> (NAE 2004)

The flat world of Friedman and the NAE world of 2020 both represent a steady development of technological and societal trends: they describe today's world tomorrow. In this chapter, we propose three different possible future worlds in 2030, some of which explore potential discontinuities in current trends. Each possibility is written as a scenario to describe what that world of 2030 might be like.

We begin by describing the general role and desired competences of the engineer today in 2011. We then adopt a scenario approach to describe three likely future scenarios for the world in 2030, which all have elements of a world that is close, crowded and creative. We describe the working environment in which the engineer of 2030 will most likely be expected to perform for each of the three future scenarios. The competences which would likely predominate or be most necessary in order for the engineer to be successful as an engineer are also identified.

The Engineer of 2011

There is no single archetypal engineer, or pattern which universally describes what engineers are, in the world of 2011. Descriptions of engineers tend to focus on what engineers do rather than on the intrinsic characteristics of what makes someone an engineer. Engineers practise in many diverse disciplines and perform many diverse roles, even within those disciplines. There are also many people who have been educated as engineers but no longer work in engineering roles.

Engineering schools have traditionally educated engineers to function effectively in technical engineering roles. This is to say that the traditional educational model to educate an engineer in 2011 will focus on developing the ability to create and apply solutions to technical problems from a knowledge and understanding of mathematics and scientific principles. The development of other skills in an engineer – for example, the ability to be innovative, to have well-developed communication skills, and to function well in teams of diverse talent – has generally been seen of lesser importance within an engineering curriculum. The engineering educator may also view the development of these non-technical skills as belonging within the domain of the workforce, that is, that it is while working as an engineer that the engineering graduate should develop such skills.

However, in recent years, there is a growing awareness of the necessity to broaden the education of the engineer: that the traditional educational model is producing engineers for relatively narrow types of jobs that are disappearing within industry. This is not to say that engineering graduates are no longer in demand far from it, but rather the skills that employers wish them to have as they exit university with their engineering degree have evolved to include a range of non-technical skills. In an important publication in 2004, the US National Academy of Engineering asked the following questions: 'should the engineering profession anticipate needed advances and prepare for a future where it will provide more benefit to humankind? Likewise, should engineering education evolve to do the same?' (NAE 2004). The NAE develops the case for 'engineers who are broadly educated, see themselves as global citizens, can lead in business and public service, as well as in research, development and design, are ethical and inclusive of all segments of society'. Evidence that change in engineering curricula must happen appears in the changing accreditation criteria for professional engineering degrees and in the literature, as described below.

Attributes of the Engineer of 2011

Let us briefly examine how engineers are educated today and what competences they are expected to possess as they graduate from university. Consider the accreditation criteria set by standards and professional bodies in the United States (ABET), the United Kingdom (Engineering Council) and Ireland (Engineers Ireland). Accreditation criteria specify 'what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviours that students acquire in their matriculation through the program' (ABET 2010). Accreditation criteria are generally mutually consistent for programmes leading to the educational standard required for professional engineering. The following paragraphs describe these composite skills.

Knowledge Skills – Engineering graduates must be able to demonstrate their knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline. They must be able to derive and apply solutions from a knowledge of sciences, technology and mathematics and must have the ability to identify, formulate, analyse and solve engineering problems.

Intellectual Skills – Engineering graduates must be able to demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

Table 7.1 Prioritised list of essential engineering skills

Essential engineering skills	
Prioritised list by employers	Prioritised list by graduates
Technical engineering	Critical/analytical thinking
Written communications	Oral communications
Teamwork	Teamwork
Oral communications	Interpersonal skills
Critical/analytical thinking	Written communications
Interpersonal skills	Learning to learn
IT/software skills	IT skills
Creativity/innovation skills	Management skills
Mathematical	Leadership
Leadership	Creativity/innovation

They must have 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.

Practical Skills – Engineering graduates must possess practical engineering skills including the ability to design and conduct experiments, as well as to analyse and interpret data. Thus the engineering graduate must be capable of using the techniques, skills and engineering tools necessary for engineering practice.

General Transferable Skills – Engineering graduates must possess the ability to work effectively as an individual but also in teams and in multidisciplinary settings. They must have the ability to communicate effectively, in writing and orally, both with the engineering community and with society at large. They should have the capacity to undertake lifelong learning. They should be capable of understanding the impact of engineering solutions in a global, economic, environmental and societal context, and they should understand the need for high ethical standards in the practice of engineering (ABET 2010; EC 2006; EI 2007).

Essential Skills Reported by Irish Engineering Graduates and Employers – A recent research study conducted in Ireland of both engineering graduates and their employers validates the attributes described above. In this study, over 8,000 recent engineering graduates (i.e. within 8 years of their graduation as engineers) from 81 different engineering programmes within Ireland were asked to participate in a survey, and 1,496 of those graduates responded to the survey. Almost 400 organisations that employed those engineering graduates were surveyed, and 74 employers responded (IOT 2011).

The summary Table 7.1 below lists the top ten skills that employers and engineering graduates reported as essential for engineers to succeed in the workplace. Each column is prioritised, so for example, for employers, technical engineering skills were more important than written communication skills, while critical/analytical thinking was more important than oral communication for the graduates.

While employers place technical engineering competence top of their list, engineering graduates place it further down their list in 11th position. That competence aside, the lists are remarkably similar and demonstrate that for both sets of people, general transferable skills such as critical thinking, communications and teamworking are considered essential for an engineering graduate to succeed.

Attributes of the Engineer of 2020

According to the NAE, the attributes of the engineer of 2020 will be similar to those of today, but made more complex by the impacts of new technology. In addition to strong analytical skills, practical ingenuity and creativity will grow in importance. Engineers will require good communication skills, management skills and leadership skills. They will require a strong sense of professionalism and high ethical standards. The engineer of 2020 will need to be dynamic, agile, resilient and flexible and capable of lifelong learning (NAE 2004).

A Close, Crowded and Creative World

During the first decade of the twenty-first century, we have observed profound changes brought about by advances in telecommunication and information technologies and globalisation. These changes do not simply affect how governments, businesses and people interact, but are paving the way towards the emergence of new social, political and business models. According to Friedman, one of the main consequences of these changes is a levelling of the global competitive field – the world becomes flat (2006). Besides being flat, the present world can also be characterised as close, crowded and creative.

The ‘close’ world is the world of disappearing barriers. With the absorption into everyday use of information and communication technologies, distance, time and increasingly cultural differences cease being barriers in many areas of life: education, work, business, social interactions, medicine and others. In education, technology provides access to growing information sources, unlimited networks of people and computers and unprecedented learning and research opportunities (Wheeler 2001). Information technologies offer more opportunities for work and access to work, as work is no longer closely connected to geography and increasingly less to time zones. In business, international corporations as well as small firms and individuals can conduct worldwide business instantaneously by searching for their trading partners online or producing and transmitting goods and services across the network (Spencer 2002).

As the world gets ‘closer’, it is also becoming more ‘crowded’ as competition for literally everything increases: jobs, market share, contracts, employees, students, projects, talent, expertise, funding and, of course, natural resources. While in the past companies would compete against other firms similar in size and capability, in the ‘close’ world they operate in a much denser environment where they face not only their traditional competitors but also new and very different entrants to their field, such as large but flexible corporations and individual freelancers (Friedman 2006). Collaboration and *co-opetition* become important factors in a ‘crowded’ world characterised by interconnected economies. In the past, success in business could be characterised by market share and by ‘winner-takes-all’ approaches; however, new business models are more nuanced and move away from pure competition towards recognition of the value of cooperative relationships that leverage value created within the network (Bowser 2011).

Of course, 'crowded' is a characteristic that applies beyond the business world. With the growing global population, there are increased pressures on the world's natural resources, such as land, raw materials and water. These pressures are likely to continue to increase with the growth of middle classes all over the world and their aspirations to reach the standards of living enjoyed currently by developed economies. On the flip side, as prosperous societies 'begin to produce enough food for people to leave the land, the excess labour gets trained and educated, it begins working in services and industry; that leads to innovation and better education and universities, freer markets, economic growth and development, better infrastructure, fewer diseases, and slower population growth' (Friedman 2006, p. 464). While additional millions of better educated and skilled people are likely to crowd the market even further, they will also bring new ideas and opportunities – making the world more creative.

As the world becomes more connected and crowded, creativity and innovation become essential in dealing with the new challenges that emerge in such a world. Drucker (2001) has proclaimed that the next society will be a knowledge society, for which knowledge will be a key resource and knowledge workers will dominate the workforce. Education is the foundation of such a society. However, with almost everyone being able to access information and knowledge instantly using information technologies, the education programmes that will help people to succeed in today's world will need to equip them with knowledge and skills that will empower them to be creative and innovative in the way they use that knowledge and the technology available to them (Friedman 2006). These programmes will also need to develop leadership skills which will be especially important in times of technological determinism in the world where capabilities create intentions (Friedman 2006).

If the present driving forces of change continue to prevail in the future, then the world described above is likely to continue on its current development path. However, it is also possible that certain drivers may lose their importance, some significant trends today may discontinue tomorrow and new forces may emerge. In effect, quite different future worlds may develop. The roles and skills of the engineer of 2030 may differ depending on what future emerges. To explore alternative future development paths, we have used a scenario approach, which is discussed in detail in the next section.

Scenario Planning and Global Scenarios for 2030

Scenarios are descriptions of plausible alternative futures that may emerge as a result of interactions between key drivers of change, trends and events. They are not predictions of the future but stories portraying different possible future outcomes (Krawczyk 2010). Usually, none of the scenarios come true, but the actual future includes elements of different scenarios. Scenarios are used for ordering people's perceptions about alternative future environments in which decisions and plans made today may play out. Through a systematic identification and analysis of drivers, trends, issues and events, scenario planning provides a better understanding of the dynamics of change and allows for consideration of a fuller range of opportunities and threats. By asking *what if* questions, it helps to uncover the underlying, often hidden, assumptions about the future and expose the areas of risk and vulnerability (Ratcliffe 2009). Scenario planning is a widely recognised tool that assists us in making better decisions about the future today.

A scenario approach has been previously used to explore the future/ideal engineer of 2020 by the NAE (2004). The scenarios developed in the NAE project examined transformational changes that could emerge from breakthrough developments across several areas of technology, rapid advances in biotechnology, a major natural disaster and global divisions caused by religious fundamentalism. The scenario stories that resulted from the exercise focused on different aspects of technological development and its consequences for an engineer of 2020. The approach taken by the authors of this chapter aims to create a set of broad global scenarios that would depict the main drivers at play in a given future state as well as explore the broader work context for engineers in 2030.

There are many different sets of scenarios portraying the world in 2030. The majority of them assume globalisation, progress in science and technology, economy, sustainability and climate change, politics and population trends, to be the key forces that will intertwine and interact creating our future up to 2030. The scenarios developed for the purpose of this chapter and presented below are based on the scenario work carried out by The Futures Academy (Ratcliffe 2005; TFA 2008; Krawczyk and Ronchetti 2009).

Scenario 1: Orange (Liberty)

This scenario assumes a continued globalisation, growing libertarianism and economic collaboration. In 2030 the world is characterised by fairly stable economic growth, although with periods of booms and busts, open markets, rapid scientific and technological advances and a fast-paced innovation. Relatively quick global economic recovery from the recession of the late 2000s re-established confidence in markets' ability to restructure and respond to challenges without strict regulation. The role of national governance has been declining, while international corporations and city-states, especially in the Far East, have been growing in power. International collaboration is mainly a platform for facilitating global competition and enhancing market efficiency. Alliances are also formed on an *ad hoc* basis to grasp opportunities of the moment or to solve burning social and environmental problems threatening profits.

The world of 2030 is a world of winners and losers. The gap between rich and poor globally and within the majority of states has widened as individualistic and materialistic values prevail. There is little coordinated global action on many serious environmental problems such as climate change. These environmental problems are left to be dealt with by free-market mechanisms. As a result, environmental problems worsen and environmental impacts, especially from climate change, are a source of increasing devastation around the world. Although growing social unrest, new waves of terrorism and increasing numbers of environmental refugees threaten peace and political stability as well as economic stability; year 2030 is also marked by exciting technological developments in artificial intelligence and bio- and nano-technologies, the launch of new web technologies and perhaps the first human travel to Mars by Chinese astronauts.

Business and industry are dominated by large global corporations with turnover exceeding the GDP of nation states. Most large corporations have moved away from a hierarchical model towards a distributed multipolar network model, which gives them much sought agility and flexibility. Worldwide 'no limits' labour market that allows for free movement of workers between countries, companies and networks fits well with the concept of 'agile corporation of 2030'. Knowledge workers usually work as freelancers or associates of 'talent' networks or agencies. 'Jobs for life' are a distant memory of the past, even in a largely privatised and curtailed public sector, while lifelong learning is a must. In most countries, people work at least until they are in their 70s, and in some other countries, there is no retirement age at all. The business landscape of 2030 is characterised by a whole spectrum of for-profit and non-profit business models, growing number of virtual companies and capabilities networks depending highly on specialised knowledge.

Scenario 2: Green (Equality)

In this scenario, by 2030, the world has undergone a major transformation. It is a more peaceful, equitable and environmentally sustainable world that maintains relative balance between civic society, governments and business. The period of prolonged economic downturn set in motion by the 2008 financial crisis led to a realisation that uncontrolled exploitation of the natural environment coupled with the exponential growth models could lead to a systemic collapse. A new agreement on climate change signed early in the second decade and the introduction by the G20 countries of a 'Better World Programme' shortly thereafter introduced a set of new financial and economic policies aimed at rebalancing society and environment with economic goals. New forms of governance that emerged provided greater access to information and increased involvement of the wider society in decision-making processes.

Technological innovations in clean-tech and bio- and nanotechnologies were directed towards decreasing human impacts on natural systems and improving quality of life for the poorest. The world of science and technology, although developing dynamically, is strictly guided by social needs and ethical concerns. There are still disparities between the rich and poor; however, the gap appears to have narrowed. Quality of life has improved globally, although for many in developed countries it has declined. In 2030 the world is a more peaceful and equitable place, but many believe that the strict rules and regulations that created it have taken away most of their freedom and are burdensome and tiresome for most.

The world of business and industry in 2030 is highly regulated and scrutinised. In many countries, entrepreneurs are frustrated with large amounts of 'digital paperwork' and countless compliance procedures that are often in turn slowed down by consensus-based decision-making processes. The power of global corporations, although subjected to various global agreements and rules, is only partially curtailed in comparison to the 'Orange scenario'. The strictest regulations are in areas of sustainability, corporate social responsibility (CSR) and ethical scrutiny of scientific and technological developments. While care for the natural environment and local societies is now a widely accepted norm, strict regulation of scientific and technological developments is met with growing resistance. Some smaller countries, which did not sign up to international agreements, increasingly attract scientists and engineers to their 'science with no limits' heavens. With a global playing field levelled up, companies move less and so do the people, with the exception of highly skilled workers frequently moving around the globe, while others usually migrate within a region.

Scenario 3: Purple (Fragility)

In this scenario, the world has been shaped by a sociopolitical backlash against the forces of change prevailing in 2000s. Long economic stagnation after the near collapse of the global financial system in 2008 combined with lack of consensus and action on global issues, such as climate change and financial market regulations, eroded trust in international institutions and processes. With the rise of protectionism and localisation of markets, in 2030 it is the nation states that have reclaimed their power from global corporations. International cooperation is now limited to the traditional domains of defence, trade and immigration, with regional alliances forming around common interests.

Neither governments nor new technologies solved the most severe social, economic and environmental problems, which are mounting around the globe, intensified by impacts of global warming; rapid, often poorly planned urbanisation; rising crime levels; terrorism; and increasing conflicts around scarce resources. People are turning back to their local communities and cultural roots in search for identity and comfort or escape into a virtual world of entertainment and gaming. Quality of life has decreased for most; however, local communities thrive around the globe increasingly addressing local problems by sharing best practices and solutions through virtual channels.

With the disintegration of the global landscape and curtailment of globalisation processes due to emergence of new political and regulatory barriers, many global corporations suffered severely leading to their contraction, fragmentation or in some cases even collapse. The trend towards multipolar networking observed throughout 2010s has been reversed, and many organisations came back to more hierarchical and vertical structures in response to a need for increased security. Many companies of strategic importance were nationalised to ensure full state control. With shrinking economies, the demand for labour decreased and even highly skilled people occasionally have difficulties in securing a job, partly due to stringent restrictions in global labour mobility. It is an employer's market, and for most workers, temporary contracts are the reality of 2030, with the exception of strategic sectors. Small companies that cannot afford highly skilled staff on their books often use expertise from local and regional sectoral networks, which allows them to have access to knowledge on a project-by-project basis. While overall the world of 2030 under this scenario is challenging, different countries cope differently with these challenges and some are quite successful in securing quite stable economic and social conditions.

Comparison of the Roles and Competences of Engineers Under the Three Scenarios

The engineering profession and consequently engineers' roles and competences will develop differently under the three potential future worlds described above. And although the total make-up of the required skill sets will be diverse, essential engineering competences, such as technical skills, analytical skills, problem-solving skills, communication skills and IT literacy, will continue to be a necessary requirement in each of these worlds. What is likely to be different are the problems and projects these skills will be applied against and emphasis on their different aspects. For example, communication skills will be equally important under all three scenarios; however, in the highly globalised and connected 'Orange' world, where engineers work in multinational teams with team members located around the globe, the ability to communicate in a concise, clear and unambiguous written manner will be a must. On the other hand, in the fragmented but highly competitive environment of the 'Purple' scenario, outspoken engineers with capability to communicate, promote and negotiate ideas and solutions as well as to engage effectively with clients are likely to succeed the most. Analytical skills are another example – necessary in all three scenarios; they are likely to be used for solving different types of problems in the 'Orange' and 'Green' worlds, for example, improving effectiveness of internet-based medical diagnostic instruments in the first one and implementing *cradle to cradle* approach in the construction industry in the second one. However, in the 'Purple', world, the analytical skills will need to be embedded in common sense to a much greater degree to make an engineer successful.

When we examine other important skills and competences that an engineer in 2030 will be required to possess (Table 7.2 provides a full list of capabilities), creativity and innovation, synthesis skills and continuous learning come to the fore. Creativity and innovation and synthesis skills will be essential in the 'Green' and 'Purple' scenarios, although again for different reasons. For example, in the 'Green' scenario, these skills will be used to solve complex environmental problems, while in the 'Purple' world, being creative and innovative will give engineers much higher chances to succeed.

Another important set of competences, although essential for only one scenario, include professional agility, commercial awareness, teamwork, flexibility to work in different environments, ability to work independently and practical skills. Professional

Table 7.2 Desirability of skills and competences under each scenario

Skills/competences	Orange	Green	Purple
Technical skills	√√√	√√√	√√√
Analytical skills	√√√	√√√	√√√
Communication (written and oral)	√√√	√√√	√√√
Problem-solving	√√√	√√√	√√√
Computer/IT/computer tools	√√√	√√√	√√√
Creativity/innovation	√√	√√√	√√√
Synthesis skills	√√	√√√	√√√
The ability for continuous learning	√√√	√√	√√√
Professionally agile	√√√	√√	√√
Teamwork (includes both physical and online collaboration)	√√√	√√	√√
Commercial awareness	√√	√√	√√√
Ability to work independently	√√	√√	√√√
Practical ingenuity	√√	√√	√√√
Flexible in working in different environments:			
(a) physical	√√	√	√
(b) cultural	√√	√	√
(c) professional	√√√	√√	√√
Systemic view	√√	√√√	√
Social and ethical awareness and CSR	√	√√√	√
Cultural awareness	√√	√	√√
Understanding of legal requirements	√	√√	√√
Language skills	√	√	√√

√ – desirable; √√ – highly desirable; √√√ – essential

agility will be an essential competence for engineers working in the 'Orange' scenario of high mobility and quickly changing working environments. Commercial awareness will be a must for a majority of engineers in the 'Purple' scenario of limited opportunities and greater economic pressures. Teamwork and flexibility to work in a variety of professional environments will be essential in the 'Orange' scenario, characterised by high levels of labour mobility between countries, companies, networks and projects. The flexibility to work in different physical and cultural environments will also be required, however, to a lesser extent. In the 'Purple' world, successful engineers will be required to be able to work independently and be able to utilise their practical skills – 'getting their hands dirty' will be part of their daily jobs. All these skills will be highly desirable in the 'Green' world, but not essential.

Engineers operating under the 'Orange' and 'Purple' scenarios will require somewhat similar sets of essential skills and competences, even if these are required for different reasons, in comparison to the 'Green' scenario. There are two key capabilities identified as essential for engineers working in the 'Green' world that we perceive only as desired in the other two worlds: having a systemic view and strong social and ethical awareness and responsibility. The 'Green' scenario envisions a world attempting to reach a balance between environment, society and economic development. The transformation required to achieve this state will need major changes, including moving away from a fragmented way of thinking about the world towards a systemic perspective. Most engineers will be required to not only think about solutions for a particular project or problem but also to understand how that problem is positioned within a given system, being ecological, transport, social, etc., and how the chosen solution will affect other parts of the system or systems. Very high ethical standards and in-depth understanding of CSR will also be a must in a world that places enormous emphasis on ecological and social wellbeing.

Amongst the remaining capabilities that engineers will likely be required to possess are cultural awareness, language skills and understanding of legal frameworks and requirements. Cultural awareness is likely to be highly desired in the ‘Orange’ and ‘Purple’ worlds, again for different reasons. For engineers working in the ‘Orange’ world, cultural awareness will be a highly desirable asset, which helps to work more effectively within multinational teams and in different locations around the globe. The growth of importance of local cultures and identities in the ‘Purple’ world will impact also the working environment. For the few engineers able to work in other countries, understanding of the culture of their new environment will help them to do better in their jobs. For the same reasons, knowledge of languages other than English will also be helpful in this scenario. On the other hand, movement of knowledge and ideas through virtual channels between different locations around the globe will require understanding of the cultural contexts within which they were produced to ensure that they can be successfully implemented in a different location. Finally, although understanding of broader legal frameworks and requirements is a desirable ability for engineers under all scenarios, it seems that it will be particularly important in the ‘Purple’ world, where understanding of legal loopholes will benefit creative and entrepreneurial engineers as well as in the highly regularised environment of the ‘Green’ scenario.

Table 7.2 above attempts to capture the above discussion by describing the desirability of a range of skills that the engineer of 2030 should possess under each of the three scenarios that we developed. Again noting that engineers practise in many diverse disciplines and perform many diverse roles, even within those disciplines, the table should be seen as a generalised summary of desired skills under three different scenarios. Again, it is worth observing the overall consistency of desired skills across the three scenarios and again compared to the earlier survey summarised in Table 7.1 above.

Closing Observations

From the analysis of the skills and competences that engineers will require for different potential worlds of 2030, it is clear that the skills seen as essential today, such as technical and analytical skills, problem-solving, IT competences and communication, will continue to be a must in any world that may emerge. However, it is also expected that the importance of other competences, such as creativity and innovation, synthesis skills, ability for continuous learning, professional agility, commercial awareness, ability to work independently and practical ingenuity, will grow going into the future. An engineer with these capabilities will have higher chances of success in any future that may emerge. Additionally, there are some new competences that may become important if the world follows a particular path, for example, a systemic view and social and ethical awareness become highly desirable capabilities in the 'Green' scenario.

A fear has been expressed that while the engineering curriculum must adapt to provide the engineer with a range of key skills over and above their technical engineering skills, it may not be adapting as fast as it needs to. What are the skills that the engineering professor must possess in order to educate the engineering student to succeed in this close, crowded and creative world? Morell and DeBoer summarise the profile of the ideal engineering professor as a technical expert with a savvy and adaptability rooted on actual engineering practice and superior communication skills and recognised as an effective teacher and mentor (2010).

Finally, consider the following rhetorical questions: if the engineering school takes students as their raw material and educates them as engineers and sends them out into the world, for whom does the engineering school educate these engineers? Is it for the benefit of the engineers themselves or is it for the organisations or companies in which the engineers will function? Perhaps in an earlier world with the prospect of 'jobs for life', it could be argued that the beneficiary of an engineering education was the company that hired that engineer. In today's close, crowded and creative world, we are transitioning from an engineering educational curriculum model that places an emphasis on technical engineering skills to one that recognises the critical importance of a range of other key skills. Therefore, and perhaps it might appear as self-evident, it is becoming increasingly clear that the beneficiary of an engineering education must first be the engineer. If the engineer can, through their engineering curriculum, acquire and develop the other necessary non-technical skills identified in this chapter, then it will also benefit the company that hires the engineer. And that should also be better for society.

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Chapter 8
Educating Chinese Engineers: The Case of Shanghai Jiao Tong University During 1896–1949

Brent K. Jesiek and Yi Shen

Abstract This chapter summarizes the early institutional history of one of China's most important and well-regarded engineering schools, Shanghai Jiao Tong University (SJTU). It shows how the university and its engineering programs evolved in tandem with national development and defense priorities from the school's founding in 1896 through the formation of the People's Republic of China (PRC) in 1949. More specifically, we look at key changes in the school's admission policies, pedagogy, curricula, and organizational structure, as well as typical career pathways for its graduates. To further contextualize this account, this chapter begins with a general history of engineering education in China from the late Qing Dynasty through the Nationalist period. This chapter should be of interest to those wanting to know more about the historical foundations of the engineering profession in China, including the role of leading educational institutions in China's national development.

Keywords China • Engineering education • Engineering profession • History • Nationalist • National development • Republic of China • Shanghai Jiao Tong University

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Introduction

In relation to social and economic development, China is often portrayed as a recent and rather dramatic success story. *The World Factbook*, published by the US CIA, nicely captures the dominant story line: "China's economy since the late 1970s has changed from a closed, centrally planned system to a more market-oriented one that plays a major role in the global economy" (US CIA 2011). One might even argue that China now plays a *primary* role in the global economy. In 2009, it moved into position as the world's leading exporter and in 2010 surpassed Japan to become the world's second largest national economy, trailing only the USA (Hamlin and Yanping 2010).

In light of such trends, many commentators have expounded at length on China's so-called economic miracle. And in line with the preceding *Factbook* quote, much of this literature portrays China's developmental arc as one of recent origin. But with 2011 marking the hundredth anniversary of the fall of the Qing Dynasty and first steps toward a Republic of China, it seems an appropriate time to take a longer view of China's development. To what extent is China's ascendency built on deeper historical foundations, going at least back to the country's Nationalist government?

There is also the question of what roles engineers and engineering have played in China's national development. As Andreas notes, "China today is ruled by red engineers" (Andreas 2009, p. 1), as evidenced by the many engineers who have held powerful positions in the upper ranks of China's ruling Communist Party. Engineering is also one of the most popular majors for Chinese students, and even conservative estimates suggest that China graduates 300–400,000 engineers per year at the bachelor's degree level (Bracey 2006; Gareffi et al. 2008). Such trends are especially notable for commentators from Western countries like the USA and Great Britain, where the number, visibility, and influence of engineers are relatively low by comparison.

As a growing body of scholarship suggests, we might better understand such trends by looking squarely at the intersection of engineering and development. Using a series of national case studies, Downey and Lucena (2004) argue that national variations in engineering knowledge and profession are often deeply intertwined with national history and identity. As a more specific example, various scholars have explored how engineers have historically constituted the French state, promoting its development through rationalized planning from within the central government (e.g., Alder 1997). In this regard, China bears some resemblance to France. Yet on closer examination, the history of engineering and development in China is replete with idiosyncrasies and discontinuities that have only begun to be studied, especially in English language accounts.

Zhu (2010), for example, has explored evolving understandings of the modern engineering profession and engineering ethics in China from the dynastic period to the present, while Kirby (2000, 2010) has examined the roles of engineers and engineering education in modern China, especially during the Nationalist period. Andreas' *Rise of the Red Engineers* (2009), on the other hand, examines the history of China's prestigious Tsinghua University from the formation of the PRC to the present. The author shows how changes in political ideology and development priorities directly impacted the structure and content of engineering education at Tsinghua, as well as the status and influence of the school's students, staff, and graduates.

By discussing the history of another important educational institution during the country's Nationalist period, our chapter makes further contributions to the English language literature on engineering and development in China. We begin with a general history of engineering education and professionalization in China from the late Qing Dynasty through the Nationalist period. We then turn to a more in-depth institutional history of one of China's most important and well-regarded engineering schools, Shanghai Jiao Tong University (SJTU), with particular emphasis on examining how the university and its engineering programs evolved in tandem with national development priorities from the school's founding in 1896 through the formation of the People's Republic of China (PRC) in 1949. More specifically, we look at key changes in the school's admission policies, pedagogy, curricula, organizational structure, and alumni career pathways. This chapter should be of interest to anyone wanting to know more about the historical foundations of modern engineering education and profession in China, including the roles of leading educational institutions in China's development.[1]

Emergence of Engineering Education

Late Qing Dynasty, Mid-1800s to 1911

While ancient China's important role in the development of science and technology is well documented (Needham and Robinson 2004), its engagement with modern engineering is relatively recent. Through most of the nineteenth century, China's dominant educational model and imperial examination system remained narrowly focused on the study of classical Confucian texts for careers in civil service, and the prevailing social hierarchy gave government officials and farmers higher status than technical professionals, craftsmen, and merchants (Wang et al. 2010). Yet after centuries of traditionalism and isolation, various influences encouraged the initial but uneven development of the engineering profession in China. In particular, a series of military skirmishes and concessions during the latter half of the nineteenth century revealed China's vulnerabilities in relation to the more technologically advanced powers of Japan and the West. In response, a "Self-Strengthening Movement" emerged in the early 1860s to promote China's national development, including through diplomacy, engagement with Western science and technology, and military modernization (Wang 1998, pp. 301–302).

[1] In fact, some of this chapter was first drafted to prepare US engineering students for research internships in China, including at SJTU, for the NSF-funded International Research and Education in Engineering (IREE) 2010 China program (US NSF Award No. 0965733).

Against this historical backdrop, Kirby reports that the first use of a Chinese word equivalent to the modern "engineer" (*gongshi* or *gongchengshi*) appeared in a government report published in 1883, and in 1888 the term was recognized as an official title by Qing officials (Kirby 2010, p. 284). As Zhu notes, such changes in terminology exemplify how the modernization and Westernization movements of the period were challenging China's deeper social and cultural traditions (Zhu 2010, p. 90). Such movements also ran parallel with creation of new indigenous pathways for technical education. In 1862, for example, the Qing government founded the country's first Western-style college, the Tongwen Guan in Beijing. While initially providing language training for China's diplomats, it also soon became the country's first school of science and technology. Foochow Shipbuilding College, on the other hand, was established in 1867 as part of efforts to upgrade the country's outdated navy. British and French influences were evident in the school's teaching staff and curricula, and it offered 3- to 5-year programs in navigation, ship design, and ship maintenance (Wang et al. 2010, pp. 5–9). By 1911, it had graduated 178 naval engineers, although some have questioned the quality of the education provided and noted that job prospects in China were limited at the time for graduates with advanced technical training (Reardon-Anderson 1992, p. 55).

Given a lack of domestic educational opportunities, in the 1870s, the Qing government also started sending Chinese students and military personnel abroad for training. Many traveled to the USA, Europe, and Japan, and some earned degrees in science and engineering (Hayhoe 1996, p. 40). One of China's most famous engineers, Zhan Tianyou, was among the first cohorts of Chinese students educated abroad, and his biography illustrates the uneven state of engineering education during this period. Zhan was fortunate to receive his bachelor's degree in civil engineering from Yale in 1881, just before the Qing government abruptly and temporarily reversed its policy and recalled all Chinese students who were studying in the USA at the time ("Imperial Students" n.d.). After returning to China, he completed a year of naval training at Foochow and soon after launched a career in civil and railroad engineering ("Imperial Students" n.d.). In fact, Zhan was the first Chinese official to hold the official Qing title of engineer, and he led a series of ambitious and successful railroad construction projects (Kirby 2010, p. 284). Given the underdeveloped state of engineering education and profession during the late Qing Dynasty, Zhan's is a story of improbable success.

During the late nineteenth and early twentieth centuries, the Qing government took a number of steps to expand and modernize the country's educational system. For example, Peiyang University was founded in Tianjin in 1895, during the last years of the Self-Strengthening Movement (Wang et al. 2010, pp. 9–10). In addition to being one of the first schools in China to wholly adopt a Western model of university education, Peiyang responded to national needs through its early establishment of rigorous 4-year programs in civil, metallurgical, mining, and railway engineering. Even more generally, legislation passed in 1902 and 1903 explicitly advocated creation of a system of higher education that included engineering universities, or *gongke daxue* (Hayhoe 1996, p. 35), and in 1905 the Emperor famously endorsed a discontinuation of the country's traditional examination system (Elman 2000).

Yet the actual implementation of such measures stalled as the power and stability of the dynasty eroded. By 1909, China had only three universities (*daxue*) with 749 students, 24 higher-level, provincial schools with 4,203 students, and 101 specialist colleges with 6,431 students. These schools were training very few engineers. For example, just three percent of students in the specialist schools were studying science or engineering at the time – as compared to 50% in law and politics (Hayhoe 1996, p. 42). As this evidence suggests, engineering education remained a marginal and immature field through the late Qing Dynasty.

Nationalist Period, 1911–1949

The history of modern engineering can often be explored by looking at the emergence and growth of higher education, professional societies, and sites of employment. During the Qing Dynasty, educational and career pathways underwent modest developments, while professional societies did not yet exist. As dramatic change swept through China during the Nationalist period, the growth and vitality of the engineering field was evident in all three domains, especially as the profession became increasingly intertwined with the government's priorities for national development and defense.

The country's educational system was one early and important target for reform, paving the way for major expansions of higher education generally and engineering education specifically. As examples of some early and important changes, the Confucian classics were ordered out of curricula, and a "university decree" in 1912 identified universities as the highest educational institutions in the country (Yang 2002, p. 32). The decree also linked universities with specific combinations of fields. For example, a given university might elect to strategically focus its mission and curricula on sciences along with agriculture, medicine, or engineering (Hayhoe 1996, p. 43).

Through the 1910s and into the early 1920s, continued social and political unrest impeded the formation of new educational institutions. Yet as the 1920s progressed, increasing political stability and national unity, coupled with supportive legislative moves, ushered in a major expansion of higher education. The number of university-level institutions increased to eight in 1917 and 35 by 1923 (Hayhoe 1996, p. 47; Yang 2002, p. 33). The number of specialized institutions of higher education, including engineering schools, also rose, and the number of students enrolled in both types of schools jumped from 23,334 in 1917 to 34,880 in 1923. Study abroad continued during the 1910s and 1920s, with many hundred Chinese students sent to the USA and Europe and thousands to Japan (Hayhoe 1996, p. 49). Many of the scholars who received graduate degrees abroad quickly moved into leadership roles in Chinese universities.

As the central government gained greater control of the country in the latter half of the 1920s under the leadership of Chiang Kai-shek and the Nationalist Party (KMT), the expansion of higher education accelerated. By 1930, there were 39 universities, and student enrollment in engineering rose to 11.5% of all university and college students (Hayhoe 1996, p. 52). This growth temporarily stabilized in the early and mid-1930s, with the country home to about 100 universities, 7,000 faculty, and 40,000 students at any given time (Xin 2001, p. 187). Yet concerns about a lack of students in the basic and applied sciences led to further reforms, and by 1937 the proportion of students in engineering was 18% (Hayhoe 1996, p. 54). Kirby similarly notes that the number of students in science and engineering doubled at government institutions between 1931 and 1936, and during the entire decade of the 1930s, the total number of engineering students increased threefold. Engineering programs at prominent schools like Shanghai Jiao Tong University benefitted greatly from major increases in student enrollment and government funding (Kirby 2000, p. 147).

The dominant style of higher education also evolved as China's universities expanded and matured in the 1920s and 1930s. American influences were evident, for example, in the use of course credit systems and formation of academic colleges and departments (Xin 2001, p. 186, Hayhoe 1996, p. 54). European influences were more apparent during the latter part of this period, especially as faculty embraced academic freedom and universities sought greater institutional autonomy. Other Western influences from this period include the widespread use of English language textbooks and an emphasis on "general education" and common curricular requirements (Xin 2001; Cheng 1965, p. 99). Yet especially in the area of graduate education, China continued to rely heavy on training abroad, with American universities alone granting more than 9,000 degrees to Chinese students between 1930 and 1954 (Guo 1998, p. 45). Perhaps not surprisingly, many of the academic programs developed during this period emulated the high academic standards of schools abroad. As one commentator noted, "In the pre-Communist period, admission to a department of science or to an engineering college was granted only after strict selective processing. For graduation, rigorous examinations had to be passed" (Cheng 1965, p. 102).

As China's system of higher education trained ever more engineers, the aforementioned Zhan Tianyou established a new organization to support the profession. Formed in 1912, the Chinese Society of Engineers (*Zhonghua gongchengshi xuehui*) initially had just 148 members (Kirby 2010, p. 284, Hao 2003, p. 41). In 1931, it merged with the Chinese Engineering Society, which was founded at Cornell University in 1918 by Chinese nationals pursuing advanced engineering degrees in the USA. Around this time, the organization had some 2,300 members – itself a testament to the profession's growth. During its early history, the group worked to promote the profession, standardize engineering education, and advance the nationalist agenda. Initially the society also strived for professional autonomy and self-regulation, but this "gradually gave way to greater cooperation with, and reliance on, the state that now educated and certified engineers" (Kirby 2000, p. 149).

As the preceding passage suggests, engineers gained prominence as the Nationalist government embraced a development ethos in the 1920s and 1930s. This opened up important career pathways as many engineers helped build infrastructure and promote urban development, including by expanding the country's communication, power, and transportation networks. Sun Yat-sen's *The International Development of China*, published in the early 1920s, was particularly influential as a technocratic and scientifically oriented blueprint for building the Republic under Nationalist rule

(Kirby 2010, p. 285). Kirby even describes Sun as "the spiritual father of the Chinese engineering state" in light of his proposals for ambitious infrastructure projects and faith in science and technology (Ibid, p. 286).

In the 1930s, the government's National Resources Commission (NRC) emerged to lead development of China's infrastructure and industries, including in anticipation of a possible war with Japan (1937–1945). It quickly became the biggest employer of engineering graduates and for a time was headed by a former president of the Chinese Society of Engineers. It recruited heavily from the leading Chinese technical schools, and especially graduates of Shanghai Jiao Tong University. As Kirby notes, the NRC was an "engineer's salvation" because it provided career opportunities in an environment that was less politicized than other government agencies (Kirby 2010, p. 151). At the same time, NRC engineers performed essential functions and achieved many successes for the Nationalist leaders they served.

The Nationalist government supported intensified industrial and technological development during war with Japan, in part relying on the growing ranks of engineers and other technical experts being trained domestically. In fact, higher education in China grew considerably during this period, and by 1945 there were 141 higher education institutions with 83,498 enrolled students (Hayhoe 1996, p. 56). And by 1944, a quarter of the country's university students were studying engineering (Reardon-Anderson 1992, p. 217). As further evidence of the profession's growth, membership in the Chinese Society of Engineers rose to 14,000 by 1948 (Kirby 2010, p. 284).

China's universities matured during the later years of the Republic, achieving a balanced integration of Chinese intellectual traditions, Western scholarly and curricular influences, and academic ideals like intellectual freedom and social responsibility (Hayhoe 1996, p. 59). This was also a time of greater harmonization across schools via standardized courses and curricula and the implementation of quality control mechanisms for teachers and educational materials. Nonetheless, such reforms did not address a long-standing problem with Chinese engineering education, namely, a lack of practical and applied training. As summarized in one account, "China's engineering curricula had been copied from European and American models and based on advanced technologies that had nothing to do with China" (Reardon-Anderson 1992, p. 217). The ramifications of this trend became more apparent during war with Japan. According to one account, "By War's end, most NRC [National Resources Commission] enterprises were overstaffed with recently trained engineers and understaffed with individuals who had practical experience" (Kirby 1989, p. 31).

To address these deficiencies, more than 1,000 Chinese engineers, scientists, and managers received supplemental training in US firms during the later years of the war (Kirby 1992, p. 201). Attempts were also made to continue many of the Nationalist government's policies during the postwar period, including those related to industrial and human resource development. Yet the legacy of wartime devastation, combined with growing political unrest, posed tremendous barriers. After 1949, many policies – and the educational institutions that grew up under Nationalist rule – were fundamentally transformed as the Nationalists fled to Taiwan, and the Chinese Communist Party formed the People's Republic of China on the mainland.

Looking back on this period, a 1965 report by the US National Science Foundation (NSF) concluded that "Pre-Communist China suffered an extreme scarcity of scientists and engineers," and added that the country graduated only 31,700 engineers from 1928 to 1947 (Cheng 1965, p. 72). Yet as the preceding account makes clear, China produced an impressive quantity of engineers during Nationalist rule – especially when one considers that much of the formation and growth of the profession and its educational system occurred during the 1920s and 1930s. And while the quality of their education can be questioned, many of the engineers trained during this period played important roles in the country's development – both during and after Nationalist rule. To further enrich this history, we now turn to the formation and evolution of one of country's leading engineering schools.

Shanghai Jiao Tong University, 1896–1949[2]

Shanghai Jiao Tong University is one of the China's oldest institutions of higher education. Founded in Shanghai in 1896 as Nanyang Public School by an imperial edict of the Qing government, the school was originally a product of the Westernization and Self-Strengthening movements. In successive historical periods, the school underwent many major transformations in response to the nation's evolving needs. From 1907 to 1920, it became an industrial school and actively expanded its science, engineering, and technical programs following Western educational models, ultimately becoming a modern engineering school. The 1920s saw further transformations at the school resulting from vigorous Sino-American collaboration in science and higher education, the growing influence of foreign educational models, and changes in the boundaries of the major engineering fields. After the Nationalist government took more control of China in 1928, the relevance of higher education to nation building was even more evident, reflected in the university's rapid growth, close cooperation with government agencies, and reputation for training the country's top engineers.

During the anti-Japanese War (1937–1945), the university was devastated after first being forced to move to the French Concession and then to Chongqing to preserve its educational system and train specialists to meet wartime infrastructure needs. Immediately after the war, Jiao Tong University returned to its home campus in Shanghai and started to recover from the ravages of the protracted conflict. However, the postwar struggle from 1945 to 1949 caused the school to be embroiled by constant student protests and frequent changes in leadership, reflecting the unsettled political condition of the country as a whole.

[2] Unless indicated otherwise, this account is translated and adapted from *The History of Jiao Tong University: 1896–1949* (History of Jiao Tong University Writing Group 1986).

From Public School to Industrial School, 1896–1920

An imperial edict issued in 1896 by Emperor Guangxu established Nanyang Public School in Shanghai, which included a middle and high school, normal (or teacher training) school, and school of foreign studies. Sheng Xuanhuai (1844–1916), who proposed the idea to the Emporer, became the first president and is regarded as the university's founder. Sheng was a key member of the Westernization Movement and among the first industrialists in modern China (Zhang 2010). He was influential and controversial as both a government official and advocate for nationalism and capitalism (Liu and Li 2006).

To promote the Westernization Movement, Sheng realized the importance of understanding and mastering foreign languages and technologies and new modes of education. In particular, he wanted to weaken the role of the imperial examination and emphasize the adoption of Western academic models and a more practical style of education (Jin 2005). Under Sheng's aegis, Nanyang Public School symbolized the alliance of capitalist practice and feudal heritage. The school initially emphasized business and political science to support the country's developmental needs and Self-Strengthening Movement.

In 1905, Nanyang Public School was transferred to the government's commercial department and renamed High Industrial School. In 1906, it was renamed Shanghai High Industrial School of the Postal Transmission Department. Around the time of the Xinhai Revolution (1911–1912) the school was renamed Grand Nanyang University. After the Republic of China was founded in 1912, it was managed by the traffic department and renamed Shanghai Special Industrial School. These changes in name and affiliation reflected the exploratory and experimental character of the school's early development. Yet its ties to the country's commercial, postal transmission, and traffic departments foreshadowed its future trajectory into fields such as economics, management, telecommunications, and transportation.

Tang Wenzhi was the school's president from 1907 to 1920. His administration emphasized a curriculum organized along the disciplinary lines common in modern Western practice in engineering higher education. The school actively expanded its scientific and technical programs to become a major engineering school, and the birth of a 4-year traffic management program in 1918 symbolized the emergence of a modern industrial school that combined education in engineering and management.

Comparing the curricula of civil engineering and electrical and mechanical engineering before and after the Xinhai Revolution reveals many changes (History of Jiao Tong University Writing Group 1986, pp. 75–76). First, the scope was expanded, from 18 courses for the old railway program to 28 courses for an expanded civil engineering program; an increase from 14 courses for the electrical engineering program to 23 courses for an expanded electrical and mechanical engineering program; and the addition of a new railway management program with 47 courses, which was equivalent to a full four years of schooling.

The structure of the school's curricula also changed, with general education requirements replaced by specialized coursework. For example, after the railway program was changed to a civil engineering program, the load of general courses was reduced from 43.9% to 27.3%, while specialized courses increased from 19.7% to 33.4%. There were similar changes of course load in electrical and mechanical engineering. At the same time, greater emphasis was directed to experiments, practice, and working experience. Many courses were specially designed and offered for hands-on practice and experiments, in part displacing the previously dominant approach of combining class instruction with experimental demonstrations.

New industrial economy and factory management programs were also added. During the late Qing Dynasty and early Republic, the country lacked experts with specialized knowledge in engineering, industrial economy, and factory management. The goal of these new programs was to train experts who could apply these types of domain knowledge to real practice. It is also notable that the factory management program was the first of its kind in Chinese higher education. It seeded the later addition of a railway management program and established foundations for a much longer tradition of combined engineering and management education at Jiao Tong University.

Nonetheless, the school was initially short on qualified staff to teach in many areas, so it imported expertise. From 1908 to1920, for example, foreign instructors – mostly American – represented about half of the school's faculty in the disciplinary specialties, and the Departments of Civil Engineering and Electrical Engineering were both headed by American professors. Yet as noted below, the faculty structure quickly changed in the 1920s as large numbers of returned student-educators replaced their foreign counterparts.

In summary, after 1911 the Chinese government's relative weakness opened an unusual window of opportunity for China's revolutionary educators. As it was transformed into an industrial school from 1907 to 1920, the school went through a relatively stable period of development, with curricula gradually reorganized and rationalized to serve emerging national needs. The school also enjoyed a certain degree of educational independence and autonomy. It still emphasized the study of Chinese literature, but followed Western educational models in engineering and technical fields, promoted application of learning to practice, and maintained strict admission requirements.

Shanghai School of Jiao Tong University, 1921–1927

After 1915 China experienced growing antagonism engendered by Japanese expansion and rising currents of Chinese nationalism. Due to persistent political uncertainties and disruptions, from 1921 to 1927 the school underwent a tumultuous phase of development defined by three reorganizations and fourteen turnovers of presidents and major administrative personnel.

This was accompanied by a merger of the Shanghai Special Industrial School, Tangshan Special Industrial School, Beiping Railway Management School, and Beiping Post Telecommunication School, all under the direct supervision of the traffic department. As a result, the previous Shanghai Special Industrial School was renamed the Shanghai School of Jiao Tong University. Thus, Jiao Tong University had three branch schools in Shanghai, Tangshan, and Beiping. In 1922, the university went through a second reorganization into two branches in Shanghai and Tangshan, each incorporating programs from the original Beiping branch. The original Shanghai School was then renamed Nanyang University of the Traffic Department. In 1927, a third reorganization led to another change in name, this time to become the First Jiao Tong University of the Traffic Department.

Ye Gongchao was president of Jiao Tong University from 1921 to 1922. He advocated an educational model imitating European and American universities and promoted development of science and engineering to protect and develop the country. During 1918 and 1919, Ye traveled to Japan, Europe, and the United States. He explored the cultural, educational, political, and economic situations of these countries and was fascinated by educational systems abroad (History of Jiao Tong University Writing Group 1986, p. 139). His ideas about education were clearly reflected in the school's educational objectives (Xia'an Publishing 1946, p. 172).

A number of other important trends also characterized this period. The general, underlying philosophy was that higher education constituted an indispensable component of the larger task of national reconstruction. The influence of the New Cultural Movement and May Fourth Movement further promoted science and democracy and led to many reforms in higher education, with particular emphasis on integrating teaching and research. Training specialized knowledge experts and conducting advanced research were especially promoted in a proposal to establish a graduate school during the formation of Jiao Tong University, but the plan temporarily stalled.

Foreign, and especially American, influences on Chinese higher education also reached a high point, with the late 1910s and early 1920s a period of vigorous Sino-American collaboration in science and higher education. American educators such as John Dewey visited China to lecture and teach, and their ideas were spread far and wide (Wang 2007). The idea of following an American educational model gained support, as many Chinese students studying in the USA returned to the country with a desire to implement American approaches in China. As a result, the deeply embedded values and social roles of the old Chinese literati gave way to modern educational ideas. For instance, credit hours for the course of Chinese literature were considerably reduced during this period. At the same time, many engineering academic associations, economic associations, and other scholarly societies were established, while academic exchanges prospered. And as research activities gained prominence on the campus, an Industrial Research Institute of Nanyang University was established in 1929.

From Shanghai School of Jiao Tong University (1921–1922) to Nanyang University (1922–1927) and the First Jiao Tong University of the Traffic Department (1927–1928), the curricular structure and instructional plan went through many changes and readjustments that reflected the evolution of modern engineering fields. Until 1927, the First Jiao Tong University of the Traffic Department featured disciplinary programs in electrical engineering (including electric power engineering, telecom engineering), mechanical engineering (including railway mechanics, industrial mechanics), and traffic management (including financial management, railway transportation management). To train specialized experts, each discipline emphasized its various technical subfields, which tended to mirror the disciplinary organization in many American and European universities.

Other changes during this period included a strengthening of fundamental courses in physics and chemistry, as well as a greater focus on experiments. Also, additional courses were offered to improve students' design ability, and greater emphasis was placed on the breadth and depth of engineering courses. For example, students in electrical engineering were required to take courses in mechanical engineering, and vice versa. A more comprehensive curricula and a heavier course load were required, featuring general education requirements, technical foundations, and specialized technical courses. Finally, English language learning was promoted, including via course requirements and annual English debates and speech contests.

The faculty structure changed during this period as well. After the establishment of the school's first engineering programs in 1906, most department heads and professors were from abroad. Yet this trend reversed in subsequent years as the number of native experts increased and anti-imperialist sentiments intensified. In fact, the percentage of foreign educators in the faculty dropped rapidly, from 42.8% in April 1921 to 26.7% in October 1921, 8.1% in October 1922, and 4.1% in September 1925. By 1927, all 52 of the school's teaching staff were Chinese (History of Jiao Tong University Writing Group 1986, pp. 170–171). Further, most faculty were graduates of Jiao Tong University who had pursued higher degrees abroad. After returning, many wrote and developed their own teaching materials attuned to the Chinese context. This indicated a major change from the school's early years, when most textbooks were simply translations of foreign materials.

Formation of a Comprehensive Jiao Tong University of Science, Engineering, and Management, 1928–1936

As the Nationalist government took wider control of China starting in 1928, the country experienced a rare interlude of peace and unity. With the KMT Party's dictatorship leading from Nanjing, the university's development paralleled a twofold process that was taking place: the improvement of higher education as an aspect of national regeneration and the extension of central authority into the country's interior to promote national unity. This was also a time when the university's reputation as a southern counterpart to other leading engineering schools, such as Peiyang College in Tianjin, was established and cemented.

In 1927, Nanyang University of Traffic Department was renamed the First Jiao Tong University of the Traffic Department. In 1928 the Nationalist government issued "Organizational Outline of Jiao Tong University." As a result, the three schools in Shanghai, Tangshan, and Beiping were merged under the name Jiao Tong University, with headquarters in Shanghai. The first Jiao Tong University in Shanghai was called the Jiao Tong University – College of Mechanical Engineering, College of Electrical Engineering, and College of Traffic Management; the Jiao Tong University in Tangshan was called the Jiao Tong University – College of Civil Engineering; and the Jiao Tong University in Beiping was called the Jiao Tong University – College of Traffic Management Sub-Division. In the same year, control of Jiao Tong University was transferred to the government's railway department.

The Nationalist government also worked to standardize programs of study across universities. In May 1928, for example, KMT political education in Sun's Three Principles of the People was mandated, requiring a dedicated set of courses and exercises. And beginning in 1933, additional ordinances were issued to govern such matters as required courses, electives, and college entrance examinations (Fairbank and Feuerwerker 1986, p. 391).

The educational goal of Jiao Tong University during this period was focused on conducting advanced research and developing specialized experts, especially for the country's transportation systems. From the spring of 1929, when the railway department initiated the reorganization of Jiao Tong University, to the fall of 1930, the whole educational system was under reconstruction to integrate it with the railway department and railway transportation system. Consequently, the university developed pedagogical methods, teaching plans, curricula, and research activities attuned to the needs of the railway department and the country's rail system. Since the university was to train experts specialized in railway transportation and construction, the graduates of Jiao Tong University were usually assigned to work in that industry.

Cai Yuanpei, a leading liberal Chinese educator of the twentieth century and an outspoken advocate for progressive and democratic reforms in Chinese education, served as president of the school from spring to autumn of 1928. He emphasized the necessity of students gaining a broad knowledge base and pronounced the importance of all three educational domains of science, engineering, and management. When Sun Ke (from the winter of 1928 to the winter of 1930) and Li Zhaohuan (from the winter of 1930 to the autumn of 1944) served their terms as president, they firmly believed that mathematics, physics, and chemistry were fundamental for scientific development. In line with this view, these three departments were at the core of a new and growing College of Science, established in 1930. Jiao Tong University continued to develop rapidly through the 1930s with the establishment of a College of Management in 1931 and further expansion of the College of Engineering. The whole educational system took engineering as a core focus, science as a foundation, and management as a key addition.

To continue developing engineering during this period, the school expanded the original civil engineering, mechanical engineering, and electrical engineering programs into colleges and added many new programs. At that time, the major transportation instruments and telecommunication tools included train, telephone, and telegram. To support railway construction and the production of locomotive, telephone, and telegram devices, the university established railway engineering, road engineering, and construction engineering programs in the College of Civil Engineering; added railway mechanical engineering and mechanical automation engineering programs in the College of Mechanical

Engineering; and placed electric engineering and telecommunication program in the College of Electrical Engineering. Thus, a comprehensive engineering education system was tailored to serve and build the country's transportation and communication infrastructures.

Scientific research activities in Jiao Tong University were also very active, mostly bound to the needs of the transportation and construction industries. At the time, the Jiao Tong University Research Institute had two divisions: industrial and economic. Their main research activities revolved around railway construction, management, and operation, and practical issues related to national economic development. From 1926 to 1936, the industrial research division accomplished 38 research projects, and the economic research division completed 16 (History of Jiao Tong University Writing Group 1986, p. 298).

The number of foreign instructors during this period also remained low. Faculty members were mostly graduates of Jiao Tong University, including scholars who had returned after studying abroad. For example, the number of such returning faculty increased from 36 in 1931 to 67 in 1936 (among which 55 were professors), representing more than one-third of the total number of faculty (History of Jiao Tong University Writing Group 1986, p. 311). The whole curricular system also still followed the American philosophy of "general education." Further, the College of Engineering and College of Science mostly based their curricula on models adapted from MIT and Cornell, and the College of Management curriculum was patterned after the University of Illinois and the University of Pennsylvania.

The growth of the school was evident in the total number of undergraduate students, which increased from 450 in 1928 to 710 in 1936. In addition, the university started to admit female students in the fall of 1927, starting with 11 female students rising to 35 in 1935 (History of Jiao Tong University Writing Group 1986, p. 312). Female students mostly majored in management, less in science, and least in engineering. From 1927 to 1937, the total number of graduates from Jiao Tong University was 1,407, almost doubling the number of graduates during the 30 years prior. There were many scholarships set up to encourage and reward good academic performance among students.

In summary, the period from 1928 to 1936 witnessed the rapid development of Jiao Tong University and was regarded as a golden age for the school before the People's Republic of China was founded. This could be attributed to a number of factors. First, there was the formation of a relatively high-quality faculty, most of whom were graduates of the university or returned student-educators who studied abroad or had work experience in industry. Second, after 1928, both Shanghai and the Nationalist government were relatively stable politically, and there was both public and government support to realize Sun Yat-sen's industrial and commercial plans. Overall, the social and political environment of the country was favorable and conducive to the university's development.

During this period, the major endeavors of Jiao Tong University included the promotion of science, social reform, and research on the Chinese economy. This agenda fit well with the government's plans for infrastructure development and was clearly aligned with the national policy of promoting science in China to replicate and augment knowledge from abroad and adapt it to the Chinese context.

Jiao Tong University in the French Concession, 1937–1940

The Second Sino-Japanese War erupted on July 7, 1937, and soon developed into a full-scale Japanese invasion of China. Building on the hard-won victory in Shanghai, the Japanese captured the KMT capital city of Nanjing and southern Shanxi province by the end of 1937. On November 12, 1937, the Japanese occupied Shanghai, and the Jiao Tong campus was devastated and taken by the Japanese military. To save the university, all faculty and students moved to the French Concession in Shanghai to continue classes.

After the university moved to the French Concession in 1938 and was turned over to the Ministry of Education by the Nationalist government, its faculty structure, teaching plans, and educational objectives changed little. However, the university experienced serious budget difficulties and student unrest. Inadequate resources, serious inflation, and price increases left many faculty members no choice but to teach at two or more institutions simultaneously or conduct other business on the side to make ends meet.

As the war intensified, many factories and corporations in coastal China moved to the country's interior. Given heavy demand for transportation engineers and management experts in these less-developed regions, many graduates from Jiao Tong University went to work there and made significant contributions opposing the Japanese and developing the interior. To encourage graduates to work in these areas, the university provided a scholarship of 450 yuan (Chinese currency at that time) to each student who was willing to relocate. It is also notable that many of the school's full-time students and graduates chose to join the New Fourth Army or go to the frontier of the anti-Japanese War or the revolutionary base at Yan An.

State-run Jiao Tong University in Chongqing, 1940–1945

By 1941, Japan had occupied much of northern and coastal China, and the KMT central government and military had retreated to the Western interior to continue their resistance. The Nationalist government of Chiang Kai-shek struggled on from a provisional capital at Chongqing City.

Due to continuing and urgent demand for engineering, management, and other technical experts in the Western interior to support rapid development of railway, railroad, and air and telecommunication systems, in 1940, a state-run branch of Jiao Tong University was set up in Chongqing. When the occupying forces took over the Shanghai school in 1942, the Chongqing branch was officially declared the university's headquarters. This period was a low point in the development of the university's academic instruction and scientific research. However, it survived the toughest period with tremendous help and donations from alumni and considerable effort from faculty and students.

Due to a lack of human and physical resources, the Chongqing branch was not able to restore all three colleges (engineering, science, and management) from the original Shanghai school. However, new programs were developed in areas such as aviation, shipbuilding, industrial management, telecommunications research, navigation, and marine engines, including through a June 1943 merger with the Chongqing Merchant Marine School.

During this period, the Nationalist government also advocated "applied science" to support development of the country's military, bureaucratic, and economic systems. Influenced by American ideas, it was a common belief among the university leaders that engineers should have broad knowledge about economics and management. The school's educational philosophy thus emphasized the integration of engineering and management, leading to the creation of programs in transportation management, commercial management, industrial management, and financial management (Mao 1943). Other pressing development needs were met through the addition of an irrigation program in civil engineering and improved curricula in aeronautical engineering and automotive engineering in the Department of Mechanical Engineering. The faculty of civil engineering also started teaching senior-year students graduate-level courses that were normally offered only in foreign countries.

The Nationalist government made its own mark on the university at this time by mandating political education and strictly controlling student activities. All first-year engineering students were required to study KMT Party principles, and monthly and weekly KMT Party events were organized for all faculty and students. The Nationalist government especially enforced military training and applied military management schemes at the university. Military training courses were required for all first-year students, with two hours per week without credits. In all regards, the university was mobilized for wartime industry and national defense.

Recovering Jiao Tong University After War with Japan, 1945–1949

In August 1945, Japanese troops in China surrendered. Jiao Tong's home campus, Xujiahui in Shanghai, had been occupied by the Japanese military during the war and was sabotaged as it was deserted. Campus buildings, educational facilities and equipment, laboratories, and library collections were all seriously damaged. Soon thereafter, the Chongqing migrant university returned to its home campus in Shanghai to restore the original school. During the return, however, a ship transporting a set of mechanical engineering, electrical engineering, and civil engineering materials and equipment sank in the Changjiang River. In addition, 20 of 60 bookcases shipped from the Chongqing campus were lost on their way back. Such accidents cast further shadows on the university's postwar recovery.

After 2 months of recovery effort, classes were finally resumed in October 1945, although the school's facilities were still in poor physical condition. By mid-April

1946, more than 1,240 students from the Chongqing branch campus had returned to Shanghai after several rounds of difficult transportation. These students, along with more than 800 students from the original Shanghai branch, reconverged at the Xujiahui campus. After the school was fully reunited in May 1946, it signaled the end of Chongqing Jiao Tong University. In 1946, the state-run Jiao Tong University was restored, and the school's staff undertook the arduous task of restoring its educational and research activities.

The educational objective of Jiao Tong University as stated by President Wang Zhizhuo in a 1948 speech to new students was based on an integrated and complementary system of three colleges, of which the College of Science emphasized basic theories, the College of Engineering focused on applications of theories, and the College of Management stressed scientific management (History of Jiao Tong University Writing Group 1986, p. 445).

During this period, Jiao Tong University had 18 academic departments, two special training programs, and one research institute. It also graduated an impressive 1,868 students from 1946 to 1949. After the university was restored in Shanghai, the College of Engineering was immediately rebuilt and expanded from three to six departments, including civil engineering, electrical engineering, mechanical engineering, aeronautical engineering, marine engineering, and industrial management, along with three special training programs in telecommunications, marine engines, and navigation (History of Jiao Tong University Writing Group 1986, p. 454). By 1947, there were altogether 2,063 students enrolled in engineering at the school.

In 1943, Jiao Tong University, in collaboration with Telecommunications Administration under the Ministry of Communications, the Central Broadcasting Management Office, the Central Electrical Appliances Factory, and the Central Radio Factory, founded a Telecommunication Research Institute. An associated graduate program was also quickly established, allowing the institute to admit graduate students into a 2-year master's program of telecommunication engineering starting in the fall of 1944. Until 1948, the Ministry of Education offered no more than 30 engineering master's degrees nationwide, 16 of which were awarded to students in this program at Jiao Tong University. Its curriculum was patterned after similar offerings at Harvard University and MIT.

Yet even with these steps forward, the national situation became ever more chaotic. As political instability and economic depression pushed the government and society to the brink of collapse, the entire population sank into a morass of frustration and fear. In this adverse environment, both the academic community and Nationalist government tried to preserve and restore what had survived the military, political, and economic disruptions and destructions of the previous decade (Fairbank and Feuerwerker 1986, p. 420). Yet these efforts also generated intense conflicts between the university and government as each followed their own goals.

In 1945, for example, less than a month after the anti-Japanese War was won, the Nationalist government announced that workers and students in the formerly enemy-occupied territories were "fake workers" and "fake students." Worrying about the influence of the Chinese Communist Party (CCP) and social unrest, and especially progressive movements led by students, the Nationalist government refused to acknowledge the student status of those who had previously studied in Shanghai and required them to register for and complete a 1-year “thought training” program. In fact, the government deprived students of their educational rights at six higher educational institutions and colleges of Shanghai, among them Jiao Tong University. As a result, these universities and colleges suspended classes, and many students were inspired and organized by the CCP members who were working underground at the time. Uniting with workers, they staged a series of petitions and demonstrations fighting for their right to study. Under tremendous pressure, the Nationalist government gave in and withdrew its decision and stopped imposing the so-called thought training. However, it still insisted that students take tests on Sun’s “Three Principles of the People.”

As the country became more embroiled in civil war and domestic unrest, in 1947, Minister of Education Zhu Jiaye ordered Jiao Tong University to stop running the departments of navigation and marine engines. The students and faculty of Jiao Tong University strongly opposed any intervention at the school by the Ministry of Education and responded with large-scale student protests to protect the university’s autonomy. The university leaders strongly resisted the prospect of government or KMT Party activities on campus. The students carried out riots and strikes, which generated a series of administrative crises at the university.

To direct resources toward civil war against the Communists, in 1947, the Nationalist government also reduced the country’s educational budget to just 2.9% of the national budget. In the same year, the Ministry of Education allocated a monthly fund of just ten million yuan to Jiao Tong University, which had actual, monthly operating expenses of more than fifty million yuan. To solve the financial and budgetary deficits, Jiao Tong University united with other higher educational institutions in Shanghai to issue a budget request and petitions to the Ministry of Education or other arms of the Nationalist government almost every month from late 1948 to May 1949.

Even more generally, the postwar years were pulling China’s system of higher education into the chaos of revolution. On May 20, 1947, students nationwide led an “Anti-Hunger, Anti-Civil War, and Anti-Persecution” campaign, later known as the “May 20th Patriotic Students Movement.” Students led demonstrations and movements that brought them face-to-face with the KMT authorities, who moved quickly to put an end to any expression of dissidence. The student protests were dispersed by armed troops. Meanwhile, the war strengthened the Communists both in popularity and as a viable fighting force. Within 3 years, Jiao Tong University became an important base for Communist student movements in Shanghai.

During the three years between the war and the founding of the People’s Republic of China, the country’s economy was sapped by the military demands of a long and costly conflict, internal strife, spiraling inflation, and government corruption. The postwar struggle left the Nationalists severely weakened and their policies unpopular. Jiao Tong University was plagued by student protests, frequent changes of leadership, increasingly destitute faculty, and a general sense of institutional uncertainty, all reflecting the unsettled political condition of the country as a whole. During this period, the president of Jiao Tong University was changed three times in an attempt to suppress political discontent and bring the school in line with the KMT’s desire for order and control. By 1949, what had been a vital and thriving system of higher education exemplified by Jiao Tong University appeared ready to unravel.

Conclusion

Describing China's trajectory from 1928 to 1937 as the "birth of the developmental state," Kirby emphasizes the important roles played by engineers during this decade (Kirby 2000). Primarily under the aegis of the railway department during this period, Jiao Tong University trained many of the technical experts who were developing the country's infrastructure. The school added, expanded, reorganized, and rationalized a series of engineering specialty programs and developed pedagogical methods, teaching plans, curricula, and research activities. Others describe the period of war with Japan as a time when the country's developmental arc peaked, and not only in ideological terms (Bain 2007). By expanding and rationalizing the government bureaucracy, forming state-owned industries, and creating supporting infrastructures in education and other sectors, the Nationalist government's state-building and defense efforts during the war were ambitious – and highly dependent on engineers and engineering. During this period, Jiao Tong University was mobilized and transformed for national unity and defense, especially after its move to Chongqing. It trained large numbers of technical experts to support the wartime industries and government bureaucracy and to develop the country's interior. New specialty programs were also created at Chongqing in key technical areas. Yet the war and its aftermath also proved profoundly disruptive, both for China in general and Jiao Tong University in particular.

After the Chinese Communist Party (CCP) took control of the mainland in 1949, the school was transformed into a narrowly specialized, Soviet-style engineering university. Then, in the mid-1950s, many of the school's faculty were ordered to leave Shanghai to help launch another key engineering school, Xi'an Jiao Tong University (XJTU n.d.). Some influential alumni of Jiao Tong University, on the other hand, led formation of National Chiao Tung University in Taiwan in 1958, and this school also traces its roots back to the founding of Nanyang College in 1896 (Yen-Hwa Yu 2008).

More recently, the story has come full circle. Today SJTU is one of the most prestigious engineering universities in China, supplying large numbers of high-quality scientists and engineers that serve as the backbone of the country's scientific and technological advancement (SJTU n.d.). Its total enrollment was 53,900 students in 2010. Today the school has 26 academic schools and departments, 63 undergraduate programs, 232 master's programs, 147 doctoral programs, and 10 state key laboratories and national engineering research centers. Among the school's more than 1,900 professors and associate professors are an impressive 34 members of China's Academy of Sciences and Academy of Engineering. The university is also very active in academic exchange programs, with over 5,500 international students on its campuses and exchange relationships with more than 100 universities worldwide.

One might be tempted to see SJTU's contemporary achievements and high rankings in engineering education and research as a historical success story for the People's Republic of China. Yet the Communists did not inherit a tabula rasa when they took control of the school in 1949. Emphasizing historical continuity, Bain has argued that there remain many opportunities for "understanding why and how the Chinese Communists kept intact, built on, and expanded existing institutions, structures, and ideologies in certain key areas of political, economic, and administrative life" (Bain 2007). Additionally, many alumni and staff who attended or worked at the school during the Nationalist period assumed important positions across China (and beyond) after the formation of the PRC. By examining the first 50 years of the history of Shanghai Jiao Tong University, including the important role it played in supporting the development of the early republic, our chapter provides part of the prologue of this much longer and larger story.

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Chapter 9
Academic Drift in European Professional Engineering Education: The End of Alternatives to the University?

Steen Hyldgaard Christensen

Abstract In this chapter, it is argued that insights from comparative studies of higher education are essential to develop an understanding of educational systems dynamics impacting on professional engineering education. Usually such structural dynamics tend to go unnoticed among engineering educators. This chapter is organised in the following way: After a theoretical framing of the argument, three examples of institutional transformations and cognitive shifts that have taken place in similar types of professional nonuniversity engineering education institutions in Great Britain, France and Germany from the massive expansion of higher education in the 1960s to the present are discussed. More precisely, academic drift processes in British polytechnics, French Instituts Universitaires de Technologie (IUTs) and German Fachhochschulen will be examined and compared. In reviewing the relevant literature, the following questions will be considered: (1) What do we know about the processes that have constituted the engineering curriculum? (2) Are such processes inevitable and irreversible? (3) What kind of tensions and dilemmas do they create? It is argued that a particularly powerful and coherent set of values and attitudes characteristic of universities may also be seen as lying at the heart of vocational nonuniversity higher education institutions, causing them to drift towards the university or imitate them as implied in the subtitle.

Keywords Vocational nonuniversity engineering education • Academic drift • Vocational drift • Mergers • Driving forces • Structural dynamics

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Introduction

The point of departure for this chapter is a personal reflection on institutional transformations seen for the past twenty five years at my own institution – Aarhus University, Institute of Business and Technology – from the point of view of the original vocational engineering school *Vestjysk Teknikum*. It has puzzled me that, in spite of the local and situated character of the institution's strategic decisions at different points in time since its establishment in 1987 the institution nevertheless seems either consciously or unconsciously to have followed a general pattern of transformations of nonuniversity higher education institutions in Europe since the 1960s.

This general pattern of transformations may be seen as related to my own institution in the following way:

(1) *Fragmented expansion.* Under the name Vestjysk Teknikum, the engineering education institution was established as a small subsidiary of the larger Horsens Teknikum in 1987 in an area characterised by a lack of postsecondary higher education traditions and institutions.
(2) *Horizontal integration.* As the first of its kind, the institution gained independence by merging with a business school in 1995, thus becoming *Institute of Business and Technology*.
(3) *Vertical integration*. In 2006, Institute of Business and Technology merged with Aarhus University under the name *Aarhus University – Institute of Business and Technology* and became part of the faculty of social science at Aarhus University.

By 2011, when this volume went into press, the name simply became *Aarhus University, Herning*. What happened in my own institution is a clear-cut example of academic drift caused by institutional and structural dynamics. Presently, these dynamics are also causing other engineering colleges in Denmark to merge either horizontally into large multi-profession institutional conglomerates or as the dominant trend with universities. In the following, examples of such processes taking place in Europe will be scrutinised from the perspective of comparative studies of higher education.

The notion of academic drift was originally coined by Tyrrell Burgess in 1972 to describe dynamics of change in higher education since the massive expansion of student enrolments in the 1960s (Burgess 1972; Pratt and Burgess 1974). However, the set of phenomena it was meant to capture is much older and has been a key characteristic of processes of professionalisation since the early beginnings of professional education. Elite status pretensions and continued striving for vertical distinctions have always acted to push educational requirements in a more genteel and theoretical direction and to make them less narrowly vocational (Collins 1979). Discussing academic drift in professional engineering education today is still important for two reasons. One reason is that it relates to historically rooted, though still ongoing, processes whereby the engineering curriculum gets constituted. The second reason is that it relates to struggles over the appropriate place or locus for educating engineers for engineering practice. In many cases, these struggles have been affected by structural dynamics that have not yet attracted sufficient attention among engineering educators.

On the one hand, academic drift at a curricular level encompasses a *cognitive dimension*. From this perspective, academic drift refers to a tension between practice-oriented and science-oriented curricula. It thus refers to the process whereby knowledge derived from practical engineering work experience and intended to be useful for industrial practice gradually loses its close ties to practice. Instead engineering knowledge becomes increasingly theoretical and oriented towards engineering disciplines, including mathematics and natural science. Regarding the extensive use of mathematics in engineering problem solving, Brosan (1972) argues: "All too often parts of such courses are concerned with playing advanced mathematical tricks which are not concerned with what a man has to do in industry; little if any time is given to alternative formulations of the same basic problem!" (Brosan 1972, p. 45). Hence science-driven curricula reflect an approach to problem solving in which science is regarded as the single most important element in the solution of practical problems. Conversely, practice-driven curricula do not imply that no use is made of theories, laws, concepts, etc., from the basic sciences. Instead they are regarded as just one resource among many for the solution of practical problems (Harwood 2006). Historically, this transition marks a shift of orientation in engineering education from a perception of engineering as an "art" concerned with creative engineering design to a perception of engineering as a "science" concerned with scientific methodology and rigour (Heymann 2009).

On the other hand, academic drift also encompasses an *institutional dimension.* From this perspective, it refers to the question concerning the appropriate locus for educating professional engineering students for engineering practice. More precisely, academic drift here refers to a tension between what is considered "noble" and "less noble" institutions (Furth 1982; Teichler 2008) and accordingly to a tension between narrow vocational training and broad professional or research-oriented academic education (Burgess 1978). Academic drift in this dimension is thus meant to capture a long-term tendency of nonuniversity higher educational systems, institutions, study programmes, faculty and the student body to strive for an upward movement in the direction of an institutional setting or curriculum that resembles that of the university as the epitome of prestige (Jónasson and Jóhannsdottir 2010). In the historical perspective adopted here, it would seem that this process has been enhanced by a dialectic of forces in the sense that *academic drift* has been a driving force in nonuniversity higher education institutions, whereas *vocational drift* has been a driving force in universities. Both processes started in the 1970s and gained further momentum in the 1990s. As a result, the boundaries between the two types of institutions have become increasingly blurred (Kyvik 2009; Kehm and Teichler 1995; Teichler 1996).

In these intertwined processes of cognitive shifts and institutional transformations, status and funding have played a prominent role (Harwood 2006). The status question has been a prominent factor in the history of engineering education in

Europe since the eighteenth century. As to funding, Seely (1993, 1999) offers an illuminating example. He has shown that the vast increase in US federal funding of engineering research related to what came to be called the military-industrial complex in the wake of World War II and the Cold War period was the decisive factor for a major paradigm shift in engineering education in the United States. This paradigm shift tilted the balance in engineering curricula towards academisation and engineering disciplines. This paradigm shift also had a pervasive impact on both professional and academic engineering curricula in Europe. In 1991, Herbert Simon noted that in the United States, there was also a "contagious effect" of such development in business schools and medical schools:

> My initial views were that engineering education needed less vocationalism and more science. As I began to understand the trends in the stronger engineering schools, I saw the same things that were happening to them were happening to the new model business education: science was replacing professional skills in the curriculum. I looked a little further, and saw the same thing going in medicine. More and more, business schools were becoming schools of operations research, engineering schools were becoming schools of applied physics and math, and medical schools were becoming schools of biochemistry and molecular biology. Professional skills were disappearing from the curricula, and professionals possessing those skills were disappearing from the faculties.
>
> (The quotation is from Skoie 2000, p. 415)

In the extension of the contagious effect of academisation noted by Herbert Simon, academic drift also refers to a *structural dimension*. In this dimension, academic drift operates across the entire nonuniversity higher education sector to transform educational systems. In many European countries, there has been a sequence of structural transformations since the 1960s starting from university-dominated systems, over dual systems and binary systems to unified systems of higher education, with stratified systems like the French as an exception. Here academic drift spans a variety of fields such as engineering, agriculture, nursing and other healthcare programmes, social work, business administration and information technology. Therefore, at this level, the term implies that there is a macrostructure of higher education and that individual institutions are not self-sustaining entities. Institutions are embedded in common frameworks of societal expectations, regulatory frameworks and cooperative or competitive linkages (Teichler 2004, 2008; Jónasson 2006; Kyvik 2009). Understanding the driving forces behind academic drift at all three levels is therefore important for professionals concerned that higher education should be relevant to their practice.

Some critics have complained that academic drift has made engineering education increasingly irrelevant to actual needs. For some of them, the issue is how to bring engineering education closer to industrial needs. For others, the decline in graduates' design skills has been a key concern. However, such concerns inevitably imply a number of more complex and intricate questions. These are the following: What processes work to transform the engineering curriculum over time? How are research priorities set? Who has a say in the kind of staff that are appointed? Which factors tend to encourage academic drift and which factors work against it (Harwood 2006, p. 70)?

Theoretical Framework

According to Kyvik (2009), European nonuniversity institutions of higher education seem to a great extent to have gone through three different though overlapping phases of transformations since the 1960s. Formulated in an ideal typical fashion, these are the following:

1. *Fragmented expansion* aiming at differentiation and diversification by means of geographical and institutional decentralisation. As a result, dual systems of tertiary education became established with a clear division between universities and the college sector. In this model, the college sector is fragmented into many small and specialised professional schools that offer short-cycle 2- or 3-year vocational courses. Each of the schools has distinct vocational cultures and is subject to different public regulations.
2. *Horizontal integration* aiming at field contraction, authority unification, institutional de-differentiation, programme coordination and regionalisation. The outcome of this process may be characterised as a gradual transition to a binary model where the college sector came to be organised in comprehensive vocational multi-profession colleges, sometimes termed polytechnics, beside the university sector. The college sector now becomes subject to a common system of regulations.
3. *Vertical integration* aiming at academisation, field coupling, student mobility, structural convergence, network building and organisational integration. The outcome of this phase is characterised by a gradual transition to a unified system of tertiary education. In unified systems, both traditional academic studies as well as vocational programmes are offered within universities. Unified systems have been created in three different ways: by upgrading polytechnics, by merging traditional universities and other higher education institutions and by incorporating professional schools into universities (Kyvik 2009).

In order to discuss academic drift processes in a European context, I have selected three institutions offering professional engineering education for further examination: British *Polytechnics*, French *Instituts Universitaires de Technologie* (IUTs), and German *Fachhochschulen*. I have the following questions in mind: (1) What do we know about the processes whereby the engineering curriculum has been constituted? (2) Are such processes inevitable and irreversible? (3) What kind of tensions and dilemmas do they create? The choice of institutions has been dictated by four considerations. First, all three institutions are examples of institutions that emerged in Europe in the 1960s and early 1970s and were expected to prepare engineering students for professional practice in a more direct manner than universities. Second, they all challenged the autonomy of universities and their conception of knowledge for its own sake. Third, they have been selected as the three institutions each in their own way have served as ideal typical cases of drift processes in comparative studies of higher education (see Kehm and Teichler 1995). Finally, the United Kingdom, France and Germany have been selected to represent three historical reference models of higher education – the Oxbridge, the Napoleonic and the Humboldtian. These reference models constitute the historical initial conditions for the shaping of engineering education and the different status and roles attributed to engineers in the three countries.

In the following, the focus is on the tensions that were latent in the three institutions since their establishment in the 1960s and early 1970s. In this period, a transition from elite to mass higher education took place. The new types of institutions were created to deal with increasing numbers, a more diversified student body and a rapidly growing need for manpower in advanced industrial societies (Slantcheva-Durst 2010).

For lack of space, I refrain from a lengthy theoretical discussion of the various interpretations of the notion of academic drift. However, to be able to compare the three institutions, four dimensions of academic drift will be needed: policy drift, institutional drift, staff drift and cognitive drift in curricular emphasis (see Neave 1978, 1979; for further elaboration, see Jónasson 2006 and Kyvik 2009). I first give a brief presentation of each of the three institutions focusing on the phases of transformations they went through, if any, and the tensions that were latent in the institutions from their establishment. Next, I discuss in which dimensions, if any, of academic drift took place in the three institutions and what kind of new tensions and dilemmas followed from these drift processes.

By using perspectives and theoretical frameworks from comparative studies of higher education, we might be able to better understand some of the forces and obstacles that engineering educators are confronted with at a structural level in their effort to swing the educational pendulum back towards engineering practice (Sheppard et al. 2009). Moreover using a comparative perspective would also make it possible to be able to better estimate the likelihood of success in attempting to reverse the process of academic drift.

Three Institutions of Professional Engineering Education in the United Kingdom, France and Germany

British Polytechnics

The so-called British polytechnic experiment may be seen as an ideal type of institutional and cognitive transformations in engineering education related to all three phases in Kyvik's phase model. By means of horizontal integration, British polytechnics were created in 1965 as a separate sector different from, but supposed to be equal in status to, the traditional university. The creation of this institutional novelty marked a transition from a dual system to a binary system of higher education. In 1992, British polytechnics were upgraded to university status. With the upgrading, a transition from the binary system to a unified system of higher education took place, and the British binary experiment can be said to have come to an end (Pratt 1997).

What makes the British binary policy so fascinating is that one of its purposes was to prevent academic drift. In 1965, Secretary of State Anthony Crosland, who was the architect behind the binary policy, warned against academic drift saying: "For more than a century, colleges founded in the technical college tradition have gradually exchanged it for that of universities. They have aspired to an increasing level of work, to a narrowing of student intake, to a rationalization of course structure, and to a more academic course content" (Pratt 1997, p. 12). With the objectives of the new type of institution, it was intended to put an end to the academic drift tradition. The objectives were set out by Crosland and justified in his speeches at Woolwich and Lancaster Polytechnics in 1965 and 1967. Here he said that the binary policy was aimed at fulfilling four main objectives (Neave 1979, p. 147):

(a) That the purpose of the polytechnics was to meet the increasing demand for vocational, professional and industrially based courses which the universities could not supply
(b) That a separate sector outside the universities but in the higher education system be created
(c) That greater public control should be brought to bear upon the new establishments to ensure their ensued responsiveness to the social and economic demands of the locality
(d) That vocational and professional education needed greater standing if the international competitiveness of England and Wales was to improve

As pointed out by Neave (1979, pp. 156–157), implementing the binary policy was not as easy as Crosland originally had imagined. The objectives appeared to be ambiguous and gave rise to a number of unresolved questions which eventually led to "policy drift" by the British government and, as a result, to the upgrading of polytechnics to university status in 1992. Some of these unresolved questions related to a–d were as follows: (a) Demands by whom? By the government? By students? By the economy? (b) Should there be some degree of mobility between the sectors with students passing from the nonuniversity sector to the university sector? How large should the proportion of university staff be in polytechnics? (c) How precisely to handle the problem that close supervision by local and central authorities had not previously prevented drift in curricular emphasis, and did not automatically ensure sensitivity to social demands or the needs of the locality? (d) Increased standing in relation to what? To university education? To general secondary education?

However, taken at surface value and interpreted in terms of curricular thrust, the above-mentioned objectives are nevertheless characterised by a strong work orientation and orientation towards the needs of the local community and industry for a skilled workforce to boost growth and competitiveness in the regional economy.

Already in 1980, the Finniston report commented on deficiencies in engineering education in British polytechnics. These deficiencies were related to an observed cognitive drift of curricular emphasis. According to Pratt (1997), among criticisms of engineering education was the harsh observation "that it was unduly scientific and theoretical; that newly-graduated engineers lacked awareness of 'real life' constraints;

that they were oriented too much towards research and development work and were not interested in working in production or marketing functions" (Pratt 1997, p. 114).

From its inception, the British binary policy created a number of tensions. First among them was the tension between institutions belonging to the "autonomous" tradition as opposed to those belonging to the "service" tradition. Burgess (1978) formulated the tension in the following way. Institutions in the service tradition

> seek to place the knowledge they have at the service of society. Indeed they believe that human knowledge advances as much through the solution of practical problems as through pure thought… In seeking to serve it takes on very serious difficulties. In the first place there is the question of service to whom? Is it the student who is to be served, society as a whole, the government?… Can the institution serve more than one? The autonomous tradition settles this by asserting the priority of the discipline.
>
> (Burgess 1978, p. 46)

Already in 1974, Pratt and Burgess noted that many of the polytechnics were seeking to escape from public control by striving to become autonomous institutions like universities (Pratt and Burgess 1974, p. 173). Moreover, in 1979, Neave illuminated the inherent problems in the service tradition mentioned in the quote. Neave (1979) noted that polytechnics generally failed in distinguishing between student demands and the demands of industry and the economy (Neave 1979, p. 147).

A second tension was of a social nature. In the original Oxbridge model, elite schooling was for the upper classes focused on the development of leadership. What counted was the development of character, not the mastery of "skills" or of vast bodies of knowledge. The curriculum was therefore dominated by classical history, literature and philosophy. There was a disdain for "technical subjects like science and certainly the economic and managerial subjects that might prepare captains of Industry" (Grubb 2004, p. 6). Contrary to this tradition, the aim of polytechnics was to educate personnel for technical middle-level positions. Crosland described the kind of students that polytechnics would be catering for in the following way:

> Perhaps they left school early, perhaps they were late developers, perhaps they were first generation aspirants to higher education who were too modest at the right moment to apply to a university, perhaps they had started on a career and thought that a technical college course would more directly improve their qualifications for doing it.
>
> (Pratt and Burgess 1974, pp. 5–6)

Crosland's description clearly indicates that what he had in mind was "working-class students" and that an important purpose of British polytechnics would be to offer these students a second chance of higher education. However, somewhat paradoxically, the social tension in the emerging binary system of higher education was transformed into a tension in polytechnics between categories of students. Here a tension arose between part-time students, evening students and sub-degree level students on the one hand and degree students and post-degree students on the other. The overall consequence was that there was a rapid expansion of the academic potential of polytechnics causing the original vocational orientation and student clienteles from industry to suffer. The final upgrading of polytechnics in 1992 and the transition from a binary to a unified system of engineering education coincided with the transition from industrialism to post-industrialism. This has led Kyvik (2009) to conclude the following:

> In many ways, the binary model should be seen as a metaphor for the old class society, where the class a person was born into was decisive for his or her social status, cultural taste, and income. In the same way, the binary divide between universities and colleges would preserve a socially constructed and socially institutionalized division between noble and less noble higher education institutions.
>
> (Kyvik 2009, p. 204)

It appears to be the irony of history that the institutional bottom-up strategy leading to institutional drift of polytechnics and to their final upgrading in 1992 to university status has had the adverse effect that polytechnics have now become the second division of the university sector. Pratt (2002) characterised the new situation in the following way:

> They can point to the maintenance of vocationally oriented degree courses, to their many part-time courses, and to greater access than old universities to student from lower socio-economic groups, 34 per cent against 20 per cent. Some have a growing research reputation. Yet they appear at the bottom of most league tables, gain only a few per cent of the research assessment exercise funding, and are struggling to attract applicants. In many respects, they are the second division of the university sector.
>
> (Pratt 2002, p. 1)

After this somewhat sketchy presentation of British polytechnics, I now turn to the French IUTs where the tensions were of a different kind.

French Instituts Universitaires de Technologie (IUTs)

French IUTs were established in 1966 to provide short-cycle 2-year course programmes equivalent with the French university first cycle (2 + 1 + 1 + 1) (Lamoure and Rontopoulou 1992). Their aim was to train skilled, middle-level graduates to assume "technical functions in productions in applied research and the services" as formulated in the founding decree of January 1966 (van de Graaff 1976, p. 195). More precisely, the aim was that graduates should be more narrowly specialised than an engineer but with a broader education than a technician.

The creation of IUTs was an attempt by the French Ministry of Education to create a new kind of institution better suited than the traditional university to cater for the new cohorts of postsecondary students (van de Graaff 1976). The Ministry of Education therefore wanted to introduce more flexible but still highly selective admission procedures, new objectives and pedagogies and open up the university to the world surrounding it. As argued by Reichert and Smith (2009), in France, "the celebrated ideal of free access and provision for all coexists with a cherished culture of selectivity that seems to be held in equally high public esteem and is not as neutral to socio-economic origins as true meritocracy would imply". This ambivalence dates back to the Napoleonic reform of higher education in France in the wake of the French Revolution in 1789 (Reichert and Smith 2009, p. 45).

The creation of IUTs as selective institutions was therefore no exception. Selectivity came in as a *numerus clausus*. IUTs were only allowed to admit students up to a prescribed capacity. Besides the traditional *baccalauréat* (or *bac*), there were three other possibilities for admission aiming at attracting high-calibre students: (1) acquisition of equivalent training in industry, (2) completion of a diploma that would grant access to university studies, and (3) obtaining validation of professional experience or previous learning (Mikhail 2008, p. 76).

The creation of IUTs may be interpreted as an attempt by the French government at horizontal integration of technical and administrative fields and fields of service provisions related to the primary, secondary and tertiary sectors of the French economy (Bernard 1973). However, in the end, the advent of IUTs added further to a fragmented and stratified system of engineering education in France. Engineering education came progressively to rest on four pillars consisting of two binary structures in which each pillar corresponded to a distinctive set of administrative arrangements. One binary structure was established for long study programmes including universities and the *grandes écoles*. Another binary structure was established for short study programmes including IUTs associated with universities and STS (*sections de techniciens supérieurs*) which were run by the *lycées*. The *lycées* were in charge of two of the four pillars, namely, the STS as already noted and the *classes préparatoires* for admission into the highest ranking institutions in the French educational system, namely, the highly selective but less research-intensive elite institutions, the *grandes écoles* (Jallade 1992; Giret 2011).

A key concern of the responsible Ministry of Education regarding the separation of universities and *grandes écoles* was a concern related to the overall rationality of the French educational system. A major problem was that it led to a waste of intellectual potential to the detriment of France's international economic competitiveness and research reputation. First and most importantly, the most gifted students were drawn into the less research-intensive but highly prestigious *grandes écoles* depriving the research system of these talents. Second, the universities were not selective, and they therefore had to cope with massification on their own (Witte et al. 2008, p. 224). This problem was related to a legal aspect of the *bac*. In France as opposed to other European countries, the *bac* confers a legal right to students who have obtained it to be enrolled in the university without restrictions (Jallade 1992, p. 134).

Turning to the IUTs, the autonomy and accountability of IUTs fell under the remit of the Ministry of Education. Since 1968, a high degree of pedagogical, scientific, administrative and financial autonomy had been assigned to IUTs. To this day, however, this autonomy has remained a subject of conflict with the university (Mikhail 2008, p. 75). Besides the Ministry of Education and the university, there was a substantial involvement on the part of the private industry and the trade union. This tripartite involvement created an uneasy position regarding function and status. The trade union in particular stressed the need for better "research opportunities for the staff and the creation of sufficient additional teaching posts so that most of the temporary staff can be regularly employed" (van de Graaff 1976, p. 201).

The vocational type of qualification offered by IUTs was conceived to be terminal leading to the diplôme universitaire de technologie (the DUT). Intensive school-like teaching and learning methods were therefore introduced in IUTs as a pedagogical innovation (see Jallade 1992). Courses were made mandatory as a general rule, attendance at courses was to be monitored, and students could be dismissed for absenteeism. Evaluation of students was not a terminal one but was taking place currently and finally added up to the DUT. IUT students were therefore expected to attend at least 32 contact hours per week, over an academic 2-year training averaging 30 weeks per year, to which a further 6–10 weeks of apprenticeship experience was to be added,[1] as opposed to the university norm of 12 h per week in 26 weeks (Jallade 1992).

As observed by Quermonne (1973) with regard to IUTs, “the staffing ratio and the special educational methods in IUTs have been so designed that students entering employment on leaving them have received an education combining the necessary technical skills with an adequate general training” (Quermonne 1973, p. 226). Regarding the general education mentioned at the end of the quotation, such general training would be of a more nonutilitarian nature and would therefore be expected to be more academically inclined. It might therefore be argued that the IUTs already from start had been charged with a dual responsibility which would later in 1999 be reemphasised for short-cycle programmes during the so-called Bologna Process, namely, to train graduates for employment as well as prepare them for further studies (Slantcheva-Durst 2010).

This dual responsibility gave rise to a tension. Although the courses were designed as terminal courses, van de Graaff (1976) noted that already in 1976 more than one third of IUT graduates went on to higher education. Since then, the proportion has been steadily increasing, indicating an institutional identity problem, a clear mission drift of IUTs and a policy drift by the French Ministry of Education (Ratouly 1975; Reichert and Smith 2009, p. 47).

Regarding the composition of the teaching staff of the IUTs, this was from start the remit of the Ministry of Education. According to van de Graaff (1976), national policy was aiming at a symmetrical, tripartite composition of the teaching staff. One third should be drawn from higher education, one third from the *lycées,* and finally one third from industry representing the relevant professions.[2] Here national policy failed. Instead this requirement gave rise to a number of tensions. First, it led to a sharp division between secondary personnel mainly from technical secondary education and higher education personnel from universities. As secondary

[1] These figures are based on personal communication with Bernard Delahousse, former teacher and head of the International Office at IUT “A” – Lille 1; actually they vary from one IUT department to the other, especially industrial departments versus business ones.

[2] To be more precise, this symmetrical dimension did not apply to the personnel composition properly speaking but to the quota of teaching hours delivered by each category, i.e. a third of the total contact hours over the 2 years was to be taught by university personnel, a second third by teachers from the lycées, and the last third by engineers or executives from the professions.

personnel did not possess the proper credentials for university employment, they could in a formal sense only be temporarily assigned to IUTs. A second tension was that if and when university personnel wanted to become involved in the IUTs, they deliberately had to sacrifice all possibility of university promotion as promotion would depend on their research productivity for which there was neither sufficient time due to a high teaching workload nor facilities in the IUTs (van de Graaff 1976, p. 201).

When the Bologna Process was launched in 1999 by the European Commission to create transparency in European higher education by gradually implementing a common scheme of curricular cycles (3+2+3) throughout EU member states, it came as a shock for higher education in France as the French degree structure was not attuned to the new system (see Malan 2004; Witte et al. 2008; Mikhail 2008). Even though the diploma (the DUT) offered by the IUTs was equivalent with the first French university 2-year cycle, it could not be considered equivalent with the proposed new first 3-year cycle leading to a bachelor's degree. Therefore, as argued by Witte et al. (2008, p. 218), the change of degree structure was an opportunity for policymakers and other stakeholders to reconsider institutional identities and the distribution of roles and status between the institutional types in the system. As a consequence, a process of curricular drift in IUTs towards *la licence professionnelle* started.

The *licence professionnelle* (bac+DUT+1) is equivalent with the new French vocational bachelor degree which was introduced in 2000–2001. The *licence professionnelle* is conferred by universities along with IUTs (Malan 2004, p. 294). The development of IUTs and the connections to more advanced levels of engineering education might be interpreted as a process that in many ways resembles what Neave (1979) has called "curriculum inversion". This concept is understood to mean that practical vocational education comes first in all engineering courses and degree programmes no matter what kind of institution offers them to ensure the employability of candidates to be followed later by more advanced theoretical studies.

German Fachhochschulen

When German Fachhochschulen started operation in 1971, the historical point of departure was the inertia and resistance to change in the German university system which was still to a high degree committed to the core values of the Humboldtian university. To be sure, its core values "autonomy", "unity of teaching and research", "unity of all knowledge", and "scholarly life in solitude and liberty" were still kept alive after the reconstruction of the German university in the wake of World War II (Rau 1993). These values were seen as the sound core of the German university after the damaging effects of the Nazi period. However, as argued by Rau, the Humboldtian values only appealed and apparently still do to a tiny fraction of students, those, namely, "who are interested in a research career or those who are in a position simply to enjoy a liberal education". According to Rau, the majority of students cannot be adequately served this way. They need and want "a vocational orientation, often look for social, political or ecological meaning in their studies, and are often rather bored by the kind of teaching which is delivered at the university" (Rau 1993, p. 40).

To accommodate the vast increase in student numbers in the 1960s, it was assumed that expenses for higher education in Germany, as well as in France and the UK, could not increase to the same extent as the growth in student numbers. Therefore, structural changes were needed in order to serve the new types of students and the needs of the labour market in a more cost-efficient way (Teichler 1996).

In Germany, the advent of Fachhochschulen in 1971 should therefore be seen as a policy response to the need for structural change. The change marked a transition from a dual system of higher education to a binary system. The binary system was created by means of horizontal integration of former engineering schools (Ingenieurhochschulen) and higher vocational schools (höhere Fachschulen). The latter were predominantly representing economic and applied social science areas. The binary divide applied to engineering education is much the same way as the binary divide in the UK. Universities and Fachhochschulen should complement each other regarding their education of engineers and the professional qualification of their graduates. The underlying concept was that Fachhochschulen were different in nature but were supposed to be equal in status to the universities. According to Taurit (1993, p. 23), the role of the universities was:

- To preserve the unity of science, the variety of disciplines and the autonomy of faculty members and institutions.
- To ensure the unity and equivalence of research and teaching, to educate future generations of researchers and to build strong communities of professors and students.
- To be the only institutions with the exclusive right to award doctoral degrees. However, in engineering degree programmes, universities had a right to award both Dipl. Ing. and Dr. Ing..

The research of universities was therefore characterised by a strong focus on fundamentals related to engineering disciplines but could also be engaged in applied research. In contrast, the profile of Fachhochschulen was characterised by the following seven features:

- Practical orientation
- Short terminal courses for direct employment leading to the engineering diploma and title Dipl. Ing.
- School-like teaching methods including periods of internships in companies
- Emphasis on teaching
- Courses attuned to the demands of the labour market
- Partnerships with predominantly small and middle-sized companies in the region
- Applied development and research

Student admission was mainly based on two different routes. Taurit (1993) estimated that in 1993, half of the students were admitted via the *Abitur* from the gymnasium plus half a year of practical training. The remainder of students were admitted via extensive practical experience acquired through 3 years of apprenticeship in a craft. The vocational orientation of Fachhochschulen was further reflected in requirements for staff employment. Professors were required to have 3–5 years of practical experience in industry after their doctoral degree. According to Teichler (1996) in 1991, on average 84% of regular academic staff were professors.

Like the policy behind British polytechnics, German higher education planners were concerned to create a stable system able to resist the pressures of academic drift from the "less noble" sector. The merit of a stable system would be its ability to counterbalance "the trend that too many want to become 'chiefs' and too few want to remain 'Indians'" (Teichler 1996, p. 128). In 1996, Teichler noticed confidently that the Fachhochschulen seemed to have achieved this goal. However, with the benefit of hindsight, it has fascinated me that Teichler, a keen educational observer of structural changes, has been proven wrong. Academic drift had not been prevented once and for all.

Already from start, there were a number of tensions in German Fachhochschulen. First among them was the degree structure. The German Dipl. Ing. is below the master degree but above the bachelor degree. To begin with, the study for the engineering diploma was planned to take 3 years, but from the 1980s, the duration of the courses increased to between four and a half and five and a half years (Grose 2000). This meant that the degree structure came out of tune when compared with the bachelor, master, and doctoral degree system. A second tension was that Fachhochschule graduates were not entitled to become master and doctoral candidates due to the terminal nature of their courses. If they wanted to study for a master or a doctoral degree, they would have to complete a university degree *in toto* (Teichler 1996, p. 126). A third tension was related to the teaching workload of faculty members and professors (18 h per week) and the possibility of doing research. In this tension was also included the question of salaries. Salaries were on average 20% lower than the salaries of university professors. Finally, even though on average 84% of faculty members in Fachhochschulen were professors, they were not allowed to train their future faculty members and professors. These tensions would appear to be unsustainable in the long run. Furthermore, since the reunion of Germany after the fall of the Berlin Wall in 1989 and the Iron Curtain, it was also an enormous challenge to integrate the educational systems of East and West Germany.

As a result of the Bologna Process starting in 1999, the unification of degree structures (3+2+3) took place both in Germany and France. However, the prime concern of the reforms was to harmonise the two first cycles. In the UK, the new bachelor, master, and doctoral degree structure was not new but already existing. In Germany, this process went further than in any other European country. As a result, the final outcome in Germany was that the gap between the two types of institutions in the binary system eroded from 1999 to 2004. From 2004 onwards, both universities and Fachhochschulen were able to offer both academic research-oriented programmes and professionally or practice-oriented programmes. This development may be interpreted as a de-institutionalisation of degree types in the sense that both types of bachelor and master degrees could be offered in both types of institutions. With the erosion of the binary divide between universities and

Fachhochschulen, Germany came very close to a transition to a unified system of engineering education (Witte et al. 2008, p. 222, Vogel 2009). Contrary to Teichler's expectations in 1996, academic drift can be said to have destabilised and eventually almost abolished an apparently stable binary system.

Dimensions of Academic Drift in the Three Institutions

To be able to briefly summarise and compare academic drift in British polytechnics, French IUTs and German Fachhochschulen, an operational definition of academic drift will be needed. Here, I draw on my introduction, and in addition, I draw on Neave (1979, p. 155). The main difference between my conceptualisation and Neave's is that what I have termed staff drift serves as the exclusive definition of academic drift in Neave's conceptualisation. Neave in turn draws heavily on Pratt and Burgess (1974). Given this relationship, it should therefore come as no surprise that British polytechnics as an ideal typical case of academic drift live up to the operational definition. In the following, I shall therefore concentrate mainly on French IUTs and German Fachhochschulen with an eye to recent mergers of Danish engineering colleges and universities (Table 9.1).

A common characteristic of the three institutions was that their objectives were similar, namely:

- Meeting the demands for vocational, professional and industrially based courses of a terminal nature
- To train middle-level technical personnel for employment in small and middle-sized companies
- The creation of a separate sector of higher education outside the universities
- Greater public control to ensure continued responsiveness to social and economic demands of the locality
- Increased standing of vocational and professional education

However, their attempts to seek parity with the university and to adopt academic values, practices, and research were of different kinds. In any event, these attempts, partly or wholly successful as they were, came to constitute a departure in terms of curricular emphasis from the above-mentioned objectives.

All three institutions were created from scratch. British polytechnics were upgraded to university status in 1992. In Germany, the gap between universities and Fachhochschulen narrowed down or simply eroded from 2001 to 2004 as the outcome of the Bologna Process. In contrast, French IUTs were nested into universities already from start. Yet a different attempt to seek parity with the university would be merging engineering colleges with universities. This attempt has been the dominant trend in Denmark since the mid-1990s. In Denmark, professional engineering colleges – former so-called Teknika – were created in the early twentieth century and were from start nested into technical schools for the crafts. In 1962, Danish Teknika gained independence from the supervision by the technical school leadership and became part of a binary system of engineering education (Frandsen

Table 9.1 Operational definition of academic drift

Dimensions of academic drift	Administrative locus	Definition	The three institutions
1. Policy drift	Central administration Regional administration	Inadequately defined objectives, failure to enforce policy, reluctance to monitor implementation of policy and to intervene at an institutional level	British polytechnics French IUTs German Fachhochschulen
2. Institutional drift	Individual institutions or institutional type	Reorganisation of course structure along academic lines, attempt to seek parity with the university sector, redefinition of institutional objectives by institutions themselves	British polytechnics German Fachhochschulen
3. Staff drift	Faculty members and departments in the individual institution or type of institution	Emphasis on advanced work, less significance attached to part-time students, or to recurrent education, increasing emphasis on academic values, practices, and research, and failure or lack of will to recruit experienced "practitioner" personnel	British polytechnics French IUTs
4. Cognitive drift in curricular emphasis	Curricular content, the teaching context or situation	Increasing emphasis on abstract theoretical knowledge, gradual reduction in emphasis attached to experience based practical knowledge, move away from a utilitarian approach to an approach focused on engineering disciplines	British polytechnics French IUTs German Fachhochschulen

and Harnow 2011). The following figure illustrates the development of Danish professional engineering education institutions from the early 1970s to the present (see Christensen and Ernø-kjølhede 2011, p. 290).

In the table, a lack of year indicates that only an informal and loosely defined association with a university has taken place presently. However, it also indicates that a future merger is likely to take place with the respective university. The end of structural reforms in professional engineering education is destined by an act of the Danish Parliament to be completed no later than by 2015 (Table 9.2).

Table 9.2 Merging Danish professional engineering education institutions from the mid-1970s to the present

University colleges		Engineering colleges		Universities		Engineering academies
VIA	←	Horsens (2008)				
		Helsingør (1995) Haslev (1997)	→	Technical University of Denmark	←	The Danish Academy of Engineering in Copenhagen (1995)
		Aalborg (1974) Esbjerg (1995)	→	Aalborg University	←	The Danish Academy of Engineering in Aalborg (1974)
		Copenhagen Sønderborg (1997) Odense (2006)	→	University of Southern Denmark		
		Herning (2006) Aarhus	→	Aarhus University		

Based on Frandsen et al. (2011, pp. 149–152)

In the table, it is noteworthy that the only institution that merged horizontally into a polytechnic type of institution presently seems to have regretted its decision and now wants to merge vertically with a university instead.

In French IUTs, academic drift took place in dimensions 1, 3 and 4. What triggered the drift process was the emergence of a changing pattern of education among entrant students, causing a mission drift by IUTs as the majority of students went on to higher education. Mission drift therefore took the form of a drift away from the original vocational and terminal nature of the course. A contributing factor here was the selective admission of only high-calibre students. The acceptance of the mission drift of IUTs by the French Ministry of Education may be seen as a clear example of policy drift. In dimension 3, academic drift took place as the originally planned tripartite recruitment of faculty members could not be fulfilled. Neave quotes Jean Capelle (senior civil servant under De Gaulle) for saying: "Disillusion with the IUTs set in when they slipped from the hands of men who practiced commercial and industrial affairs as part of their daily life… Instead they have turned into talking shops (*institutions bavardes*) – sub-universities run by a surplus of students from doctoral seminars or under the aegis of university chair holders" (Neave 1979, p. 151). The quotation, which of course in itself is no valid evidence, indicates that increasing emphasis was put on academic values, practices and research. Finally, drift in dimension 4 set in during the Bologna Process where the degree structure became gradually attuned to the bachelor level (*bac* + DUT + 1), therefore causing the 2-year courses to drift towards the 3-year *licence professionnelle*.

As I have shown, the German binary policy attaching different roles and status to universities and Fachhochschulen was relatively stable from the early 1970s until 1999 when the Bologna Process started. In itself, there was nothing in the Bologna Process that indicated that the binary system could not be sustained after the harmonisation of degree structures. However, in addition to the Bologna Process, the current German reform agenda is concerned with the introduction of market-oriented, competition-based academic self-governance by hierarchical structures and powerful management positions like in many other European countries (Vogel 2009, p. 1). Moreover, as argued by Witte et al. (2008), the policy formulated by German state actors and advisory bodies started to drift “as the state actors and advisory bodies’ perception that Fachhochschulen were doing a better job than universities in providing relevant higher education at moderate cost to large numbers of student, certainly contributed to their willingness to narrow the status gap between universities and Fachhochschulen” (Witte et al. 2008, p. 225). As a result, there is clear evidence of academic drift in dimension 1. The de-institutionalisation of degree types is evidence of institutional drift and a blurring of institutional boundaries in dimension 2. In dimension 3, it would be difficult to speak of academic drift related to recruitment of staff and the professoriate in Fachhochschulen as Fachhochschule professors are tenured academics with years of experience outside academia. However, there is a difference between university professors and Fachhochschule professors. University professors “insist that defining their own standards, applying their own scientific judgement, and making decision about their own affairs on the basis of criteria that reflect the inner logic of the academic world”. These values form an integral part of their professional identity and are deeply rooted in the Humboldtian principle of “solitude and freedom” (Vogel 2009, p. 1). Contrary to that Fachhochschule professors regard managerial and market-oriented reforms as aligned with their professional identity.

Regarding cognitive drift in curricular emphasis – dimension 4 – there is clear evidence of cognitive drift in curricular emphasis. The original terminal nature of the curriculum has been changed and adapted to a new degree structure and the need by students for higher educational credentials to be able to compete in the job market. However Fachhochschulen may still be devoted to their professional mission, the difference is that they implement this mission in a more academic mode than before (Jónasson 2006). Moreover, Fachhochschule professors, according to Vogel (2009), perceive their substantial teaching obligation as a prime threat to their professional identity. This is an indication that research and in particular applied research would better fulfil their normative professional ideal and therefore might be expected to have spillovers to the teaching function in the sense of gradually shifting away from being work-based to being text-based instead. Jónasson (2006) has argued that in general “the new combined institution assumes to all intents and purposes the character of the higher-prestige institution” (Jónasson 2006, p. 9). However, Fachhochschule professors do not have an individual obligation to be research-active. The research obligation rests only with Fachhochschulen as an institution. The current ambition of Fachhochschulen is to improve their research conditions and to obtain the right to award doctoral degrees (Vogel 2009, p. 5). To the extent that Fachhochschulen succeed in fulfilling this ambition, a number of tensions and dilemmas are likely to occur.

Kyvik and Skodvin (2003) have argued that a new type of tensions and dilemmas related to status and funding is likely to emerge when nonuniversity institutions are trying to emulate university values, practices and research. In so doing, it has been evidenced in the same type of institutions in Norway that they gradually became entangled in the following eight tensions and dilemmas related to allocation of resources and recruitment of staff (Kyvik and Skodvin 2003, p. 205):

- Allocation of resources – R&D versus teaching
- Distribution of R&D resources – quality criteria versus need for developing research skills
- Distribution of R&D resources – institutional versus individual rights and obligations
- Research-based teaching versus dissemination of advanced knowledge[3]
- Recruitment of staff – research abilities versus professional experience
- Distribution of R&D resources – specialisation versus breadth
- Vocational- and regional-oriented research versus discipline-oriented research
- Institutional control of R&D versus the staff's own preference

Conclusion

In 2006, Jónasson (2006) argued that a combination of academic drift and the effect of credentialism might be used to predict the convergence of institutions and systems of higher education under conditions of further expansion of higher education. A summary of his argument would also serve as a summary of the overall argument that I have been trying to advance in this chapter. In the three institutions examined here, two main drivers of structural change may be observed. On the one hand, there has been a general trend since the 1960s towards quantitative expansion and massification of higher education. On the other hand, massification has been countered by structural transformations and diversification of national educational systems. The prime objectives of structural transformations have been (1) to ensure that higher education contributes to the economy, (2) to accommodate increasing numbers of an increasingly diversified student body in more cost-efficient ways, and (3) to take enrolment pressures away from the university. Furthermore, structural dynamics have become increasingly complex as they have moved beyond the nation state to a transnational level. Even though the increase of engineering student enrolments might appear to have been relatively smaller than elsewhere in the educational system, professional engineering education has nevertheless been affected by the above-mentioned structural dynamics, but in various ways as it has been shown.

[3] Building research capacity in former nonuniversity institutions implies that both faculty members and students should be acquainted with the scientific culture, scientific methods and developments within their field. Moreover, building research capacity also relates to the question of research-based education. In 1998, the Danish Ministry of Science, Technology and Innovation listed 5 interpretations of research-based education indicating the scope of the concept: (1) instruction in research methodology given by active researchers, (2) instruction given by active researchers within their research area, (3) instruction given by researchers, (4) instruction given in institutions governed by researchers and in which the course material has been developed by researchers, and (5) instruction given in institutions which are under supervision of research institutions and in which the course material is developed by researchers (Skoie 2000, p. 412).

At a descriptive level, Kyvik's phase model captures a general pattern of institutional transformations in the nonuniversity sector. As it has been argued in this chapter, British polytechnics and German Fachhochschulen have developed in accordance with the model, whereas French IUTs differ from it. Whether institutions fit the bill or not may be due to historical initial conditions which have been described in the three historical reference models of higher education. However, what is lacking in Kyvik's phase model is a causal mechanism which would be able theoretically to provide a causal explanation of the above-mentioned structural transformations and the functioning of academic drift. Such framework for causal theorising has been elaborated by Jónasson (2006). Jónasson has termed his approach the credentialing perspective. The credential account implies

> that public policy initiatives and the demand for a skilled workforce should be seen as external modulating or facilitating factors rather than as primary causal mechanisms. The students (according to this account the primary consumers of education), along with their aspirations for educational credentials, are interpreted as a substantial driving force behind educational expansion. The academic faculty, on the other hand, having a similar aspiration for status, affect the internal structures of institutions and of the system, partly as a response to institutional growth and partly as a method to gain status, which leads to the academic drift that we witness.
>
> (Jónasson 2006, p. 4)

According to this account, structural transformations of institutions and educational systems take place in three steps. First, students in search of credentials to be able to better compete in job markets drive educational expansion. Second, academically inclined faculty members on the one hand and institutional leadership on the other with similar aspirations for individual and institutional status are looking for an opportunity to revamp internal institutional structures along academic lines, thus creating a push for structural change of the educational system. For institutions, this means that they would be more competitive in the market for higher education as the credentials they award are more attractive to larger numbers of students than those offered by institutions with less prestige. It also means that they would be better able to attract high-calibre students, thus allowing themselves to be more selective. Third, the constant push created in the first two dimensions is modulated by policy initiatives and manpower planning considerations. According to this perspective, the Bologna Process should not be seen as a causal mechanism but rather as an opportunity for policymakers and other constituencies to reconsider institutional identities and the distribution of roles and status between the institutional types in the system.

I shall now return to the three questions that were posed in the abstract, namely, (1) What do we know about the processes whereby the engineering curriculum has been constituted? (2) Are such processes inevitable and irreversible? (3) What kind of tensions and dilemmas do they create? To answer the questions in the inverse order, the third question has already been dealt with at the end of the previous section. The eight tensions and dilemmas presented here may be seen as of a general nature. They almost inevitably will arise when former nonuniversity institutions try to emulate academic values, practices and research. Regarding the second question I tend to share the view put forward by Jónasson (2006). According to him, academic drift is a primary characteristic of long-term educational development of nonuniversity institutions and higher education systems. It should therefore be seen as an irreversible process and a natural part of the trajectories of educational institutions and systems. Generally, transformations take place in moments of opportunity provided by external state, public, private or transnational agencies. However, the void after the transformation of institutions may need filling by a new type of short-cycle institution, and the process can go on once again. Regarding the first question, it has been shown how the three institutions came into being with a clearly defined mission and a clear vocational emphasis in the curriculum that eventually was exposed to cognitive drift. However, here we should be more cautious to generalise as pendulum movements between theory and practice historically have been seen many times in engineering education as demonstrated by Harwood (2006) and Heymann (2009).

In 1979, Neave (1979, p. 157) pointed to a particularly powerful and coherent set of academic values and attitudes that worked against the objectives set for the three institutions. It is not unlikely that these values and attitudes will continue to exert their influence in professional engineering education as pressures for higher credentials are steadily increasing. The elements of this value system are the following:

1. That higher education is based upon a concept of personal autonomy
2. That higher education is distinguished by its grounding in research
3. That dissemination of knowledge requires the academic to work at the cutting edge of his/her chosen field – at the boundary of discovery
4. That staff should be of the highest quality, such quality being judged in terms of scholarly performance
5. That institutes of higher education cannot develop effectively if, at the same time, they have to attend to the demands of nondegree students
6. That students, if they are to derive the fullest benefit from higher education, must be full-time

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Chapter 10
Governing Engineering

Anders Buch

Abstract Most people agree that our world faces daunting problems, and, correctly or not, technological solutions are seen as an integral part of an overall solution. But what exactly are the problems and how does the engineering "mindset" frame these problems? This chapter sets out to unravel dominant perspectives in challenge perception in engineering in the USA and Denmark. Challenge perception and response strategies are closely linked through discursive practices. Challenge perceptions within the engineering community and the surrounding society are thus critical for the shaping of engineering education and the engineering profession. Through an analysis of influential reports and position papers on engineering and engineering education, this chapter aims to identify how engineering is problematized and eventually governed. Drawing on insights from *governmentality studies,* this chapter strives to elicit the bodies of knowledge, belief, and opinions in which engineering is immersed. Thus, the overall objective is explorative. By investigating the language, practices, and techniques by which engineering is governed, this chapter points to the presumptions, stipulations, and "limits" of the dominant discourses that shape our thinking about engineering and engineering education. Thereby, the analysis adds a critical input to the ongoing debates on "the future of engineering."

Keywords Engineering challenges • Challenge perception • Response strategies • Governing engineering

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Introduction

Technology is an integral part of the modern world – both in regard to solutions and problems. Engineering – understood as the profession that deals with bringing about and implementing technological change – has thus become an endeavor of the utmost significance to modern society. Correctly or not, technological solutions are seen as the answer to most of the problems we face today, and ingenious engineers are struggling to solve the problems. But what are the problems and how does the engineering "mindset" frame these problems? Is engineering education – as practiced within engineering schools and universities – capable of providing the right kind of knowledge and the relevant skills for engineers to deal effectively with the problems? Thus, does engineering education face the challenges of our times? When engaging in these vital questions, it is worth dwelling on the specific character of the challenges, how they are perceived, from which perspectives, and how they are interwoven with the response strategies.

So, what are the challenges to engineering and engineering education? Is it to invent and develop new solutions to the most pressing problems we face in society today? Certainly, but what are these problems and who defines them? Recently the National Academy of Engineering put together a list of 14 challenges ranging from making solar energy economical to providing access to clean water (www.engineeringchallenges.org). Likewise, concerned engineers are reflecting on their roles and responsibilities in dealing with challenges like security and privacy concerns, corporate social responsibility, and sustainability (Douglas et al. 2010). Numerous reports, position papers, and academic articles from governmental bodies, engineering societies, concerned engineers, and reflective scholars in the USA and Europe have described the challenges facing engineering (e.g., ATV 1997, 2000, Duderstadt 2008, 2004, 2005; The Ministry for Science and Technology and Innovation 2005; Sheppard et al. 2008; Williams 2003). Should they be taken for granted as they are stated? What is the status of the challenges and the accounts? Are they inevitable in the sense that the categories reflect essential – or even objective – features about the position of engineering within society? It is certainly clear that the challenges described have a reified status. It is not up to the individual to define the challenges otherwise.

The categories of challenges represent socially established facts that are widely taken for granted in the sense that people adhere to their existences and act according to their realities. To adopt a terminology of John Searle (1995), it could be said that the "challenges to engineering" are *objects* in the sense that they are in the world. They are ontologically subjective but epistemologically objective items. Thus, "challenges to engineering" is a socially constructed category that is established through people's actions and beliefs about the role that engineering is playing – or ought to be playing – in society. It is clear that the challenges would not be there if people did not subscribe to their relevance. Likewise, it is also clear that the challenges are real in the sense that people abide to the existence of the challenges.

Where does this leave us as researchers? One way of approaching the study of engineering challenges would be to accept the objective status of the challenges at face value and without further ado. The task would then be to investigate how the challenges could or should be met in engineering education through, e.g., pedagogic and didactic measures, redefinitions of core curricula, specification of learning outcomes, dealing with congestion problems within engineering curricula, and optimizing teaching. This approach is surely tenable, but there is risk of contradiction if it is not accompanied by further reflections on the status of the challenges. The challenges point to different problems and vindicate different approaches to engineering education.

The fact that the challenges are produced and sustained through social processes calls for a more critical and reflective approach. It is thus fruitful to investigate how and why the challenges are construed and perceived in the way they are. This kind of approach inscribes itself in the broad research tradition of "social constructionism" and post-structuralist analysis. The label of this research tradition is indeed vaguely defined and often driven to extreme positions. Therefore, it is worth pausing to define the approach in more detail. Using Ian Hacking's (1999) conceptual clarification of types of "social constructionism," the approach can be clarified further. Constructionism in relation to challenge perception can be stated in three successive steps:

1. The challenges should not be taken at face value. It should be recognized that the challenges are brought into existence and shaped by social events, forces, and history, all of which could well have been different. Thus, the contingency of the shaping of challenge perception in engineering practice should be recognized.
2. Furthermore, it should be recognized that the responses to the stated challenges are diverse and often mutually incompatible. It is thus unproductive to reform engineering education on the basis of an unreflected acceptance of (some of) the stated challenges.
3. And lastly, it is mandatory to produce a more nuanced and cogent picture of the challenges to engineering practice in order to reform engineering education.

This "social constructionist" argument is reflected in Foucault's post-structuralist research methods. According to these methods, the aim of the researcher is not to judge whether – in our case – the stated challenges are true, justified, or deserving of any other epistemic, normative, or moral privileges. The goal of the researcher is instead to describe and analyze *how* the challenges have gained their authority within specific regimes of knowledge/power. The format of this book chapter does not allow us to engage in a fully fledged historical investigation of challenge perceptions within engineering. Instead I will – inspired by approaches from social constructionism and post-structuralism – discuss challenge perception and response strategies in engineering in order to investigate how various agendas are set and how various discussions are framed. This discourse analytic approach does not aspire to do justice to all nuances and perspectives in the current discussion of challenges to engineering. The aim of our discussion is to call attention to the dominant positions taken within the debate and to illuminate the premises of these positions. The ambition is thus explorative and critical in Foucault's sense of critique (Foucault 1988). By unfolding how the challenges to engineering are *problematized* and *articulated* according to different positions and hegemonic knowledge/power regimes, the limits, horizons, and tacit assumptions of these positions are explicated and thus exposed to critical reflection. It is clear that challenge perception and response strategies are closely linked through discursive practices that frame and interpret engineering in specific ways. Drawing on insights from *governmentality studies* (e.g., Dean 2010; Miller and Rose 2008; Burchell et al. 1991), I will elicit the bodies of knowledge, belief, and opinions in which engineering is immersed and that are mobilized in order to govern the future of engineering. Finally, I will point to formative questions that are pivotal to the debate of the future of engineering.

Challenges

In the public debate it is often claimed that engineering is challenged. Although the engineering profession has been very successful in establishing its position within modern society, various voices raise concern regarding the future of engineering. In many western countries governmental committees are established to deal with the challenges facing engineering. Likewise engineering societies and interest groups, academia and industrial federations, and private companies are voicing their concerns and developing response strategies in order to deal with the perceived challenges. But although there seems to be agreement about the fact that engineering is challenged, opinions differ when it comes to specifying the nature and characteristics of the challenges. Thus, perceptions seem to differ. It is useful to sketch some dominant claims about the challenges facing engineering.

In one line of argument, "challenges to engineering" are not really challenges in the sense that engineering is threatened or confronting a crisis. The "challenges" are in reality not specific challenges to engineering, but rather challenges to our planet, humankind, society, etc. When The US National Academy of Engineering in 2010 published a list of 14 grand challenges for engineering (www.engineeringchallenges.org), the list contained problems such as "provide energy from fusion," "manage the nitrogen cycle," and "secure cyberspace." These grand challenges are not challenges *to* engineering but rather *for* engineering. In fact they seem to be opportunities for engineering to get funding, engage in business, and raise the prestige of the engineering profession in general. It is the voices that point to challenges *to* engineering that will be of interest here.

Another type of argument can be found in reports and analyses from governmental bodies, industrial federations, and political "think tanks." To exemplify this type of argument, let me refer to reports produced in a Danish context by The Ministry of Science, Technology and Innovation (2005) and by The Danish Academy of Technical Sciences (ATV 1997, 2000). The title of the 2005 report is "More and Better Engineers." Among other things the reports claim that the Danish society will have a shortage of 13,000 qualified engineers in 2020 unless drastic measures are taken to recruit more students in engineering education.[1] The report construes this development as a problem for the Danish society because the economic growth and welfare are highly dependent on technological innovation (supposedly delivered by engineers). Furthermore, the quantitative problem is supplemented by a qualitative problem. The reports indicate a gap between the competencies supplied by engineering education (today) and the competencies demanded by (future) employers. Because of this gap the western societies and their businesses will be left behind in the global competition. This line of argument thus states that the labor market for engineers is determined by the societal need for engineering services and products, and the engineering profession must adapt to changing needs of customers. The engineers must be aware of the dynamics of the market and have commercial insight in order to be employable. The challenge perceptions grouped in this category are mostly functionalist in the sense that they strongly emphasize the preeminence of the market system as the driver for change in engineering. Challenges are posed by society and should be met by the engineers. The engineers are the servants of society, delivering neutral technical solutions that can be put to use in accordance with the priorities and needs of the market system. For brevity, let us label claims of this type *the market challenge.*

Another set of challenges relates to the category of *social responsibility* on the part of the engineers. Here engineering is viewed as a pervasive and powerful enterprise that affects the lives of all living creatures on our planet (e.g., Douglas et al. 2010; Duderstadt et al. 2008, pp. 29 ff., Clough 2004). According to this perspective on challenges to engineering, engineers must take the responsibility upon them and work to improve living conditions for all men and the environment in general. The important challenge facing engineers nowadays is not so much grounded in the argument that engineers must meet the expectations of the market (although the proponents of this position do not see a conflict between the market challenge and the social responsibility challenge). Instead the real challenge for engineers is to change society into a better place. Ethical motives are at the root of this perspective.[2] Challenges are not primarily seen as something that should be reacted to. Instead the proactive and transformative element in engineering is stressed (e.g., Duderstadt et al. 2008, p. 71). The real challenge for engineering is to employ the engineers' skills and knowledge in ways that serve humankind and sustain the environment. In this perspective engineers must strive not to let technology deteriorate into one-dimensional technical fixes. Instead technological solutions must always take social aspects into consideration. Via socio-technical solutions and innovative design, the engineers can help to create a better world. Being a socially responsible engineer implies working with the social and technical elements as a heterogeneous assemblage. Engineers must improve their social skills and learn to frame and solve problems in ways that have the *real* problems in mind.

[1] Similar arguments are produced by, e.g., Duderstadt (2008, p. 25) about the US context.

[2] Interestingly it is rarely seen that these ethical arguments are developed into political convictions.

A third category of challenge perception sees the challenges of engineering in relation to the internal evolution of the techno-scientific complex and *engineering knowledge*. Science and technology has changed dramatically over the last decades (Hård and Jamison 2005; Jamison et al. 2011). New disciplines and areas of research such as information technology, biotechnology, media technology, and nanotechnology have proliferated and transformed engineering practice in radical ways. In this light Rosalind Williams (2002) has challenged the engineering profession by asking exactly what it is about. The traditional engineering disciplines fail to grasp the new areas of research and industrial production. The techno-scientific complex with its many new disciplines is extremely diversified and hard to comprise within the engineering curriculum. Thus, the main challenge from this internal perspective on engineering practice relates to defining the core elements and unifying features of engineering knowledge. This challenge has very profound and practical consequences for engineering education and engineering identity. What should engineers know and what should be at the core of engineering curricula? Is it mathematics, physics, and chemistry or are these traditional scientific disciplines not the essential ones? If not, what should be put in their place? This third category of challenge perceptions revolves around epistemic questions, and it is appropriate to refer to it as the *knowledge challenge*.

The challenges to engineering developed in the literature can thus roughly be summarized in the three categories: the market challenge, the knowledge challenge, and the challenge of social responsibility. Proponents often sketch their arguments with elements derived from more than one of these categories. But it will become clear, however, when I look closer at the proposed response strategies that respective proponents align their arguments within specific discursive frameworks that give priority to one specific category of challenge perception. Let us investigate this further.

Response Strategies

The three categories of challenge perception reflect specific kinds of response strategies. Let us investigate the specific story lines of the strategies.

The *market challenge* is generally met by response strategies that focus their attention on the role of the engineers within the company. The strategy's fundamental claim is that engineers need to supplement their technological skills and competencies with commercial qualifications (e.g., ATV 1997, 2000; The Ministry of Science, Technology and Innovation 2005). The engineers still have to undergo an advanced technological education, but a proportionate part of the education has to qualify the engineers within economics, (project) management, sales, investment analysis, negotiation, etc. In this line of argument, the yardstick of relevance for engineering qualifications is the company's needs. The argument states that in order to stay competitive, the companies need practically oriented engineers that are able to develop technological products and solutions in the most cost efficient way and in accordance with the costumer's requests. The desired virtues are flexibility, practicality, the ability to optimize, being market driven, customer focused, and agile. In short, this strategy could be called the *business strategy*. It suggests that technical universities and engineering schools collaborate with business schools or even better devote a significant part of curriculum to management studies (e.g., ATV 1997, p. 6, suggests that at least 10% of the curriculum be dedicated to management disciplines). The business strategy also recommends that engineers be trained in communication skills, collaborative skills, abilities to enter into cross-disciplinary innovation projects, etc., but there is no mention of critical reflection and other competencies typical of the liberal arts. The skills and competencies recommended by this response strategy are primarily instrumental. The engineer is thus positioned as a highly skilled practitioner with the ability to serve corporate enterprises in designing, implementing, and optimizing production for the overall motive of profit. The ideal is the corporate engineer or the "organization man" (Whyte 1956/2002). It is no surprise that the advocates of this strategy are foremost private sector companies, industry, and liberal governments that praise the free market as the ultimate regulating mechanism for designing engineering education. On these terms education should ideally be designed according to functionalist principles dictated by market needs. The business strategy has no special interest in engineering or engineering knowledge per se. It sees engineering as a convenient concept to label highly proficient people who are skilled within technology and business.

The challenge of social responsibility is met by strategies that highlight professional ideals for engineering (e.g., Duderstadt et al. 2008; Douglas et al. 2010; Clough 2004). Professional standards, codes of conduct, and ethical standings are fundamental to these strategies. Entering the engineering profession invests individuals with privileges and powers but also places responsibilities on the practitioners. The argument of these strategies holds that being educated and trained as an engineer is not just a matter of acquiring technical knowledge and skills. It is also a matter of entering a special culture that honors special values, holds scientific and technological knowledge dear, and aspires to certain virtues. In this sense, the argument claims, engineering is unique and unified. The overall focus of the engineering profession should be to serve humankind, protect our environment, improve living standards, etc. Gaining personal profits or serving the interests of industry may not be in conflict with this focus, but it must always be subordinate to the professional ideals. The strategies dealing with the social responsibility challenge are thus united in their confidence in professional ideals and practices. The professional strategy thus positions the engineer as a modern "hero" who is preoccupied with developing a better world for humankind. But the strategies have different answers regarding the character of professionalism. Thus, Duderstadt (2008, p.v) recommends that engineering is transformed into "…a true learned profession, similar in rigor, intellectual breadth, preparation, stature, and influence to law and medicine, with extensive postgraduate education and a culture more characteristic of professional guilds than corporate employees." The profession becomes the habitat and unifying point of departure for engineering practice. But what is characteristic of this practice? One answer stresses that engineering practice is about solving problems and designing and building artifacts that work. The CDIO movement testifies to this down-to-earth mission (Crawley et al. 2007). Another branch of the professional strategy to the social responsibility challenge is directed by a focus on (large-scale) socio-technical systems (Williams 2003, pp. 51 ff.). In this perspective engineering is all about designing socio-technical systems and managing their complexities, dynamics, etc. Regardless of the specific interpretation given to engineering practice, the strategy holds that the profession is unified and should play a major role in dealing with the challenges humankind faces today. Thus, the profession should aspire to a higher end. Proponents of this strategy do not strive to alter engineering education by bringing in new supplementary disciplines as management or economy. Instead they propose that engineering education should be transformed into having the status of a liberal art (Duderstadt 2008, p.v) along with the natural sciences, social sciences, and humanities. It should be interdisciplinary by nature and practice-based, and engineering schools should work closely with industry to achieve this goal (e.g., Douglas et al. 2010). Furthermore, the practice of engineers should be regulated by professional licensing requirements. It should come as no surprise that the professional strategy finds its proponents in engineering professional societies and bodies, some engineering schools, and among individual engineers working in industry that stress professional standards and moral obligations in engineering.

Finally, *the knowledge challenge* to engineering also calls for a strategy. This strategy, however, is fundamentally different from the above mentioned insofar as it does not meet the challenge by trying to reinvent or reframe engineering. On the contrary, the strategy states that “Engineering is less and less a separate realm and more and more an integral part of both science and business” (Williams 2003, p. 40), and further:

> In a hybrid world, engineering can thrive only as a hybrid. Today it is most dynamic at its peripheries, where it is most engaged with science and with the marketplace. Inevitably the profession formerly known as engineering will multiply into a much wider variety of grades and types of levels, because engagement with technology has far outgrown any one occupation. The future of engineering lies in accepting rather than resisting this multiplicity.
>
> (Williams 2003, pp. 80–81)

In embracing this trend Williams thus advocates what might be called a *hybrid strategy* in response to the knowledge challenge. This hybrid strategy observes that engineering is disintegrating *and* expanding its range at the same time. In accepting the disintegration and lack of autonomy of the engineering profession, she recognizes that the education of highly skilled professionals engaged with technology no longer is the privilege of technical universities and engineering schools. In recognition of the ubiquitous role of technology in society, it must also be recognized that “engineering” is expanding its domain of relevance. In consequence the proper habitat for the education of the “engineer” of the future is the university: “Engineering education must rejoin higher education in an adventurous mix that brings together information technology, the sciences, the social sciences, the humanities and the arts” (Williams 2003, p. 83).

Contrary to the business strategy and the professional strategy, the hybrid strategy does not propose that the domain of engineering be supplemented by other disciplines (management) or transformed into a learned profession governed by licensing requirements. Instead it proposes that engineering should be reconceptualized according to changes in technology. The production of (technological) knowledge and innovation has increasingly become multidisciplinary and even transdisciplinary (Gibbons et al. 1994; Ziman 2000; Nowotny 2008), and this calls for a "hybrid imagination" (Hård and Jamison 2005; Jamison et al. 2011) of the entrepreneurs, technologists, and scientists of the future. According to the hybrid strategy, education of these innovators are situated in universities that comprise multiple disciplinary approaches and compose curricula by bringing in knowledge from different academic fields to solve problems of importance to civil society and companies. Thus, the hybrid strategy encourages dialogues with industry and civil society – although it is unclear how far this dialogue should bring the students away from the academia. The proponents of this strategy are mainly situated within academia.

Governing Engineering

The three strategies outlined above do not only answer the challenges to engineering – they can also be seen as a means of governing engineering. As already mentioned the challenges and the strategies are closely linked. Thus, the strategies provide answers to the challenges to engineering. But the linkage is more profound than just answering the challenges. The strategies provide overarching interpretative frameworks for defining, discussing, and answering the challenges to engineering and *a fortiori* the future of engineering. The strategies are the medium in which governance exists rather than its instrument. To paraphrase Foucault, the strategies install an intrinsic logic of a regime of practice by framing situations and setting the limits for what is possible to think and argue (Foucault 1980). The strategies of regimes are the producers of truths, knowledge, authority, and rationality. They are embodied and represented by social institutions, logics, material-discursive practices and the intentions of individuals, but the strategies are in themselves nonsubjective assemblages of all the elements that conduce the conduct of actors. By problematizing engineering in accordance with specific and distinct challenge perceptions, the "response" strategies define, demarcate, and advance the territoriality of the engineering mission and set visions and directions for the advancement of engineering practice and engineering education. It is thus naïve to regard the strategies as plain responses to objective challenges. In fact the strategies should be seen as the producers of the challenges. Likewise it is naïve to search for response strategies that cover and encompass all the stated challenges. It would not only be impossible on a practical level to honor the recommendations to engineering education set forward by the business strategy, the professional strategy, and the hybrid strategy (due to the congestion problem of curricula) – it would also be inconsistent in regard to the visions and missions of the respective strategies.

It is important to realize that engineering is not only governed by direct legislative and economic conditions, institutional interests, and political initiatives in relation to education and the job market. Engineering is also governed in much more subtle, discrete, and indirect ways. The strategies thus also work as disciplinary powers through our culturally mediated dispositions or dispositifs (Foucault 1972, pp. 3–17), i.e., through regimes of knowledge – relatively stable constellations of beliefs, values, knowledge, and techniques. Foucault called this conduct of conduct *governmentality* (Foucault 1991): by subjectification into specific strategies, we conduct our own actions and those of others in a wide variety of contexts. As an example the ethos of engineering expressed in what I have labeled the professional strategy has a disciplinary effect on the practices of individual engineers. This ethos is induced in subjects through technologies of education and socialization at technical universities and engineering schools and reinforced in engineering communities.

The three strategies that I have detected in the literature on challenges to engineering can thus be seen as prevailing discourses that afford the conduct of practitioners in engineering as well as other actors engaged in domains of technology, education, knowledge production, etc. The discourses afford and restrict the conduct of practitioners and actors through the development of logics, rationalities, and techniques that give guidance and orientation for future actions, judgments, decision making, framing, ways of seeing and perceiving, etc. The discourses, however, do not determine future action in accordance with a prespecifiable *telos*; the continuation of practice is contingent and the product of conflicts, negotiations, and reproductive actions that needs closer historical investigation. Alas, the format of this chapter does not allow us to indulge in genealogical investigations of engineering practice. Thus, it must suffice to gesture to the three strategies found by examining influential Danish and American texts on challenges to engineering. In the table below I have tried to capture some essential features of the three response strategies detected in the texts (Table 10.1).

Conclusion

Through the analysis, I have documented the prevalence of three distinct strategies in influential contemporary Danish and American texts on challenges to engineering: the business strategy, the professional strategy, and the hybrid strategy. In applying the analytical tools of governmentality studies, it is possible to see these discursive strategies as a means of governing the territory of engineering by developing visions and missions for the domain. Our constructionist and post-structuralist approach to challenge perception in engineering has thus enabled us to penetrate the texts in ways that do not take their accounts at face value; instead the texts are read as "voicing" different discursive narratives that strategize the future of engineering. Secondly, it can be recognized that the strategies – in accentuating and propagating different narratives – cannot be aligned or unified. Although some of the analyzed texts do contain arguments borrowed from more than one of the three strategies, it is clear – on a general analytical level – that the strategies are distinct insofar as their foci and goals vary. The strategies are thus incompatible in the sense that they promote

Table 10.1 Narratives and response strategies in engineering

Narrative/strategy	The business strategy	The professional strategy	The hybrid strategy
Challenge to engineering	To remain competitive on a national, organizational, and individual level	Recognition of responsibilities in relation to humankind and nature	The disintegration and proliferation of technological knowledge
Vision for engineering	More and more proficient engineers	Abidance by and elevation of the engineering profession	The engineer as the reflective knowledge worker
Mission of engineering	To optimize profit and secure economic conditions for welfare	To improve living conditions and secure welfare through technological solutions	To produce new knowledge and engage with the community
Authoritative principles of the strategies	The market system, company's demand for competencies, employability	Engineering virtues/professionalism/ solutions that work	Reflection, innovation, knowledge production
Subjectification/the ideal of engineering	"The organization man"	"The modern hero of technology"	"The hybrid imagination"
Proponents	Industry/policymakers	Professional engineering bodies/ engineering schools	Academia, social scientists
Consequences for engineering education	Collaboration between business and engineering schools, practical curriculum	Establish engineering as a distinct new liberal art/an academic discipline	The fusion/absorption of engineering curriculum in higher education

different agendas, have different groups of proponents that try to advance these agendas, and delimit the territoriality of engineering in different ways.

Where does this analysis leave us? The analysis of this chapter has been explorative and critical in the sense that the challenge perceptions of influential texts have been problematized (Foucault 1988) and scrutinized in order to explicate their implicit presumptions and related response strategies. In the public debate about the future of engineering, challenges are often seen as self-evident and inevitable and thereby establishing an authoritative departure for specific response strategies in relation to engineering education, engineering recruitment campaigns, etc. By closer inspection, however, it is clear that the challenge perceptions are not rooted in neutral observations but are part and parcel of discursive formations and narratives that enable the perspectives, ambitions, and visions of actors. In establishing the linkage between specific challenge perceptions and response strategies, the analysis has made the hegemonic projects of regimes of engineering practice explicit and thus exposed them to reflection and critique. The approach of governmentality studies enables us to conceive the governance of engineering practice as the discursive subjectification of engineering identity and thus elicit new avenues for educationalists seeking to reform engineering education.

The perspective has significant implications for the study of engineering education. It thus compromises the soundness of traditional "gap analysis" in engineering education. Our analysis shows that the conception of challenges is not an independent corrective factor that can guide educationalists in designing "adequate" educations that can produce the "necessary" competencies and thus "close the gap." Challenge perceptions and response strategies are part and parcel of discursive formations and distinct narratives. Reforms of engineering education end in deadlocks when educationalists try adjusting curricula in accordance with the "demands" of the labor market or according to "professional criteria." One obvious reason is that the various strategies that inform challenge perceptions pull curricula in engineering education in different directions by setting different standards for the "adequacy" of engineering education. Engineering education cannot be reformed by providing more information about labor market demands or making more "precise" specifications about engineering professionalism. The conversation on engineering education needs to change.

I suggest that the conversation on reforms in engineering education should pay more attention to how engineering work is practiced in different contemporary contexts and how engineers construct their engineering identities. Not because this information should yield objective correctives for reforms. But because more nuanced descriptions of diverse engineering practices could provide us with a richer picture of how engineers apply their engineering knowledge and skills in diverse contexts and settings, and what problems and challenges they face on a daily basis, and in their efforts to manage and develop their careers. It is important to have more specific knowledge of the processes of subjectification and socialization in engineering education and in various forms of engineering work in order to investigate *how* discursive practices and strategies guide and govern students and engineers. Nuanced and cogent descriptions of the subjectification processes in engineering education and engineering practice have the potential of redescribing and thus reframing engineering in an idiom that transgresses the narratives of the dominant discursive strategies. In order to reform engineering practice and education, we must have knowledge of how engineering is actually governed. This is only a first – but necessary – step in advancing the research agenda that can provide us with new knowledge to shift the governance of engineering education and practice.

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Chapter 11
Historical Tensions in Engineering Education: European Perspectives

Andrew Jamison and Matthias Heymann

Abstract Ever since institutions for educating engineers first began to be established in Europe, there have been a number of fundamental tensions as to how that educating should best be conducted, what it should consist of, and who should do the educating. These tensions are based on different styles or approaches to engineering education that have developed historically in different parts of Europe and which have led to what we characterize as "theory-driven," "practice-driven," and "technology-driven" approaches. This chapter explores some of the historical roots of these tensions in medieval Europe and briefly traces their developmental trajectories through the subsequent formation of institutions of engineering education. It has been written as part of PROCEED (Program of Research on Opportunities and Challenges in Engineering Education in Denmark).

Keywords Engineering • Education • History • Cultures • Perceptions • Challenges

Introduction

In the continual attempts to reform or improve or otherwise change engineering education, we can see a number of underlying, deep-seated historical tensions at work. Different approaches to engineering education, based on different perceptions or meanings of engineering and engineering competence, compete with one another

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in both the formulation and implementation of educational activities, not least in deciding on the kinds of nontechnical, or contextual knowledge that should be included (Jamison 2009).

Many educators and educational authorities consider business, marketing, and other “entrepreneurial” skills important to add on to the curriculum; in the belief that engineers who are trained in such skills will be better able to operate in the global marketplace, others contend that including too much of such extracurricular material in the educational process detracts from the scientific character of an engineering competence, and still others stress the need for fostering a “hybrid imagination” that integrates an understanding of social and cultural contexts into science and engineering education (Jamison and Mejlgaard 2010). Since these different approaches to contextual knowledge are based on different perceptions of engineering, they tend to pull attempts to reform engineering education into opposing, even contradictory, directions.

While there is basic agreement that there are rather large and fundamental challenges facing engineering in the contemporary world – climate change, social justice, and the emergence of new fields of technoscience, like biotechnology and nanotechnology, to name merely some of the most urgent – there is anything but agreement about how best to prepare students to meet the challenges. The underlying tensions tend not to be resolved but avoided, and it can be suggested that a more open and reflective attitude to those underlying tensions can help achieve more sustainable changes and improvements in engineering education.

In this chapter we want to explore the historical roots of these tensions, by tracing them back to different meanings, or perceptions of engineering that emerged in medieval Europe. It is our contention that these different perceptions of what engineering is – and, with them, what kind of competence engineers should have – have had a significant influence on the ways in which engineering education came to be institutionalized both among and within the different European countries. In this, as in so many other aspects of science and engineering, there are some fundamental cultural differences that continue to affect contemporary developments.

In any case, in regard to engineering education, different approaches, which we characterize as “theory-driven,” “practice-driven,” and “technology-driven,” have contended with each other during the past 250 years, and if the tensions between them are ever to be resolved in a satisfactory manner – most importantly, perhaps, in establishing mutually acceptable European-wide standards and evaluation procedures – it can be of some importance to reflect on their historical roots.

On the one hand, “theory-driven” approaches to engineering education build on a long academic or scholarly tradition that came to Europe with the first universities in the eleventh and twelfth centuries and which has strongly affected the institutionalization of engineering education, especially in France and southern Europe. These approaches emphasize the imparting of scientific knowledge to engineers to be through an educational process consisting largely of “book learning.” The curriculum tends to have its core in the various branches of mathematics and those natural and physical sciences most related to the particular engineering field being studied. The perception of engineering that informs these approaches is that of the applied scientist, whose competence and professional identity is based on translating or transferring theories and concepts of the "basic" sciences into one or another instrumental materialization, to turn scientific facts into technical artifacts and/or artifactual systems. In order to apply science successfully, the engineer needs to have what has been termed an "encyclopedic" knowledge of the sciences rather than a specialized knowledge of any one science. This theory-driven approach to engineering education was institutionalized, first at the *Ecole Polytechnique* in Paris, and then spread as a polytechnical or encyclopedic model throughout the industrializing world in the course of the nineteenth and twentieth centuries.

"Practice-driven" approaches, on the other hand, build on a practical or artisan tradition that has emphasized training of the various technical skills that are involved in engineering work through an educational process consisting largely of "learning by doing." The perception of engineering that informs these approaches is that of the skilled craftsman, whose competence and professional identity is based on a practical knowledge of how particular things are made and how they might be used in order to solve or "fix" problems in the real world. As such, the engineer needs to learn particular techniques, or "tools of the trade" – e.g., drawing, measuring, modeling, testing, and more recently, programming and computer-aided design and simulation. These approaches to engineering education represent an institutionalization of the master-apprentice forms of training that have characterized artisanal workshops throughout history and which in medieval Europe began to take their modern form in the guilds and in relation to the large construction projects of the eleventh and twelfth centuries (cf. Gimpel 1976; Long 2001). Already in the sixteenth century, at Gresham College in London, a "practice-driven" approach to engineering education was instituted, where craftsmen could learn the various skills and techniques that were relevant for their work, and in the nineteenth century, the mechanics institutes and other technical schools played an important role in educating engineers, especially in Britain.

While these two opposing ideal types have provided the basic models for institutions of engineering education, not least in France and Britain where they originated, there has also been a third approach or set of approaches which builds on what might be termed a "synthetic" tradition, in which the theoretical and practical components of engineering work are combined and the educational process is thus a mixture or hybridization of book learning and learning by doing. The perception of engineering that informs these approaches is that of the technologist, or technological innovator, whose competence and professional identity consists of knowing how to combine or synthesize theory and practice in particular processes of technological development. Already in the twelfth century, the German metallurgist Theophilus depicted the "diverse arts" as a distinct form of knowledge making that was both theoretical and practical, and, in the sixteenth century, Paracelsus combined theoretical chemistry with training in medical practice in his controversial attempts to reform university education. In the nineteenth century, in some of the newly established German scientific and technological universities, this kind of integrative approach to engineering education came to be institutionalized in the form of laboratory-based learning, situating a good part of the educational process in specific sites or settings that had been explicitly created for the purpose of linking theoretical and practical knowledge (Fig. 11.1).

Perception of the engineer	applied scientist	skilled craftsman	technologist
Identity, values	academic/ professional	commercial/ entrepreneurial	cooperative/ responsible
Professional competence	theoretical	practical	synthetic
Type of knowledge	objective/ analytical	constructive/ instrumental	situated/ contextualized
Educational approach	scientific	technical	integrative
Form of learning	"by the book"	"by doing"	"hybrid imagining"

Fig. 11.1 Engineering traditions

In this chapter, we explore the historical tensions between these approaches to engineering education in a highly schematic fashion from the "birth" of Europe to the present. We begin with a brief visit to the premodern lifeworlds of medieval Europe, where engineering, both for theoretical and practical reasons, came to take on different meanings and roles in society, and then trace the developmental trajectories of the different approaches through the subsequent formation of institutions of engineering education in the nineteenth and twentieth centuries.

The Three Europes

The underlying tensions that have affected engineering education during the past 250 years have their roots in the very different historical experiences that have taken place in different parts of Europe, leading to what Thorstein Veblen (1915/1968), in comparing the history of technological development in Germany and Britain at the beginning of the first World War, called different "modes of habituation" – industrial workshops in Britain and dynastic feudalism in Germany.

There were fundamental differences, Veblen contended, between the ways in which technology and engineering had developed in Britain and Germany, which he explained both in mental and physical terms. As opposed to the "hybrid character" of the German peoples which had fostered what he termed their "higher range of habits of thought that are spoken of as idealistic, spiritual, transcendental," the British, because of their isolation, had become more matter-of-fact and material in their habits of thought, "seeking efficient causes and finding these causes in a shape that continually suggests craftsmanlike workmanship" (Veblen 1915/1968, p. 107,

p. 114). This had been because of what he called the "insularity of the Island" which meant that in the absence of the other, "higher and more idealistic canons of logic and categories of generalization, the commonplace Englishman…speculated in whatever engaged his curiosity by help of the categories which habitually lay in his mind and by use of the logic which his workday occupations had taught him the force of" (ibid, pp. 111–112). Like everything Veblen wrote, the book combines history and anthropology to make fascinating conjectures about the ways in which economic and technological development is shaped by broader cultural factors. And while many of his specific arguments can appear overly speculative and downright dubious in terms of their explanatory value, he was, as the saying goes, on to something.

However, it is to be explained that, by the time of the Renaissance and the emergence of the European nation-states, engineering in the British Isles and northern Europe had developed a characteristic "style" and set of meanings that was rather different from that of engineering in the Mediterranean countries, and both were in turn different from the kind of engineering that was carried out in the Germanic or central European countries. We will not attempt to explain these differences in any detail in this chapter, but will merely point to some aspects that have proved to be significant for the further development of engineering education. In doing so, we make use of a model comparing national styles in science and technology that has been applied to historical experiences in the Scandinavian countries (Jamison 1982, 1987, 1991).

The first element is the very different sorts of belief system or religion that characterized the premodern European "civilizations" (cf. Rietbergen 1998). In the north, the pagan civilizations in Britain and Scandinavia worshiped gods that were more like the earlier Greek gods of antiquity than the one God – be it Christian or Muslim – who would come into Europe from the south and the east. The pagan gods were much less holy and in many respects much more humanlike in their contradictory urges and passions than the big-letter God or Allah, and as such they were not to be found in a kind of superhuman or nonhuman realm but were rather integrated into everyday life. They were mentors, providing practical guidance in how one might live, rather than lords, dictating commandments about how one should live. In the east, the "barbaric" tribes that wandered into Europe from Asia concocted a range of what might be called hybrid religions, combining elements from China and the near East with more indigenous beliefs. While in the south engineering thus came to be oriented primarily to honoring the glory of God, by building houses of worship and doing good works in His behalf, in the north engineering was instead largely a matter of survival, expansion, and conquest following the exemplary behavior of the gods. In the east, it was a bit of both.

A second major difference derives from the geographical and physical conditions (cf. Davies 1996). Whereas in the south the land is fertile and the seas are warm, northern Europe is much colder and the environment was much more difficult to domesticate. The central and eastern regions are again something of a mixture with a range of conditions falling somewhere between the two poles, in regard to climate and geography, and as such the kinds of engineering that came to be practiced would be substantially different. The exploitation of nature was much more challenging in the north than it was in the south. In order to survive in a cold and inhospitable climate, technical ingenuity needed to be given a different orientation or focus than in the south, where engineering, from the time of antiquity, was seen as a kind of human reworking of natural materials rather than a direct exploitation of natural resources. In central or eastern Europe, the more varied geographical conditions kept things and people in a more fragmented and dispersed state for somewhat longer than in the rest of Europe. It would not be until the eighteenth century that the fiefdoms and principalities of central and eastern Europe would begin to take on a more unified character, and as such, engineering would have a more diversified set of meanings than it would have in the north and the south.

Finally, the different forms of social and spatial organization that emerged in the different regions of Europe would come to influence engineering and engineering education in different ways. While there would be a landed aristocracy throughout Europe in the Middle Ages, they would build their castles and their fortresses and eventually their towns and their cities and their states and empires in somewhat different ways, depending on the processes of socialization or modes of habituation that took place in the different regions. While they all resemble one another in their basic functionality and structure, the cities of Europe also differ in important ways, with London centered around finance and commerce, Rome defined by its artistry in the name of God, and Berlin mixing styles and traditions in a kind of continual spirit of hybridity. The engineers who constructed them followed different precepts and principles, and these different traditions would subsequently lead to rather different approaches to engineering education when more formalized institutions were established in the modern era.

Medieval Transitions

Already in the twelfth century, the different meanings of engineering had come to be articulated in different ways in the different regions of Europe. In the south, where the universities first began to be established, the twelfth century brought with them a rediscovery of the writings of Greek and Roman antiquity, as well as a new more academic form of theology that included what has been called a "religion of technology" (Noble 1997). In the writings of Hugh of St. Victor in Paris, in particular in his *Didascalion de studio legendi* written in the 1120s, a knowledge of things technical was given a new kind of religious meaning and recognition in the scholarly world.

This was a time when the works of Aristotle, translated into Latin from Arabic, were beginning to be reread in Europe, and Hugh, like many a twelfth-century schoolman, came to include the "mechanical arts" (or *techné*) in the classification of knowledge, as Aristotle had done in his *Nicomachean Ethics*, but the early Christians had not done. But Hugh went further than most in suggesting that the mechanical arts did not merely represent a form of knowledge of their own, but that instruction in them could very well have a role to play in the university curriculum.

Hugh's interest in the mechanical arts would not be shared by most of the scholastic philosophers who would follow and come to be in charge of the medieval universities and the development of their curricula in the ensuing centuries. The scholastics viewed the mechanical or technical arts as non-scholarly, especially after the heated disputes over Aristotles's writings in the thirteenth century, and it would not be until a new kind of humanist philosophy entered into the academic world in the fifteenth century that engineering education would begin its long journey into the universities. In this respect the rediscovery of the lost worlds of magical and alchemical knowledge and, not least, the mysteries of mathematics among humanist philosophers helped to open the scholastic mind to the kinds of "experimental" methods that would be so important in the scientific revolution to come.

In northern Europe, the attitude to technology among the scholars would be somewhat different. In the thirteenth century, Roger Bacon in Oxford, who later seems to have left the university to live and work at a Franciscan monastery, wrote that "I have learned more useful and excellent things without comparison from very plain people unknown to fame in letters than from all my famous teachers" (cited in Ovitt 1987, p.119). Although it is unclear if he provided actual education in technical matters at Oxford, Bacon took a great interest in the mechanical arts and apparently interacted with many of the more active inventors in the thirteenth century, many of whom were monks in his own Franciscan order that was rapidly spreading across Europe, bringing an interest in exploring the hidden mysteries of nature with them, as their founder, St. Francis of Assisi had done (Gimpel 1976; White 1978).

As in southern Europe, however, Oxford and later Cambridge would develop a curriculum that had little place for instruction in the mechanical arts, since they were seen as distinctly lacking in scholarly sophistication in comparison to the theological and philosophical sciences. There would be a somewhat greater interest in mathematics and physics at Oxford than at most of the southern European universities, which perhaps was one of the contributing factors to the later scientific and industrial "revolutions" that were to be especially important in Britain as compared to southern Europe.

In central Europe, there seems to have been a closer connection between scholars and the craftsmen already in medieval times. The famous treatise of Theophilus, *De diversis artibus* from the early twelfth century, written by a metallurgist who is thought to have lived in a Benedictine cloister somewhere in northwestern Germany, has long fascinated historians of technology for its passionate defense of craftsmanship as a form of religious devotion and its affirmation of an active relation to God as being part of the scientific life rather than a merely spiritual or contemplative one. Lynn White has called it a "thoughtful, theologically grounded handbook for the literate and sensitive craftsman," and it seems to have been written as a response to the denigrating attitude to craftsmen among the scholars of the time (White 1978).

It is worth noting that, as with Christianity, universities came significantly later to eastern and central Europe than they did in the south and west. The first university in the area was established in Prague in 1347 (followed later in the century by Vienna, Erfurt, and Heidelberg, among others), and so technological development, and with it the societal importance of the mechanical arts, had thus advanced to a significant extent from the primitive state they had been in when the first universities had been created in Italy and France some 250 years earlier. By the time printing with movable type was invented – by a learned artisan in Germany in the 1430s who apparently spent some time studying at Erfurt – a number of scholars, especially in central and eastern Europe, had begun to show a more serious interest in things technical, and in the sixteenth century, they would produce a so-called technical literature depicting machines and describing technological development processes (Sawday 2007). Georg Bauer, or Agricola, was one of the pioneers in this regard, combining theoretical and practical interests in his *De Re Metallica* in 1566 in a similar way to what Philippus Aureolus Theophrastus Bombastus von Hohenheim, or Paracelsus, had done somewhat earlier in regard to chemistry and medicine (cf. Hård and Jamison 2005).

Institutionalization of Engineering Education

The different historical experiences and their associated meanings, or perceptions of engineering, would subsequently lead to quite different processes of institutionalizing engineering education (cf. Jørgensen 2007). In France, engineering educational institutions would draw on the scholarly tradition as it was reconstituted in the eighteenth century (Crawford 1996). It was among the so-called *philosophes* – Voltaire, Rousseau, Diderot, and Condorcet, in particular – that the mechanical arts would come to be seen as a fundamental source of human progress and enlightenment. In the influential *Encyclopedie* coedited by Denis Diderot and the mathematician Jean Le Rond d'Alembert and published in the 1750s and 1760s, the various trades and technical arts were presented as forms of knowledge on equal terms with the more traditional academic subjects (cf. Hård and Jamison 2005). Later, after the revolution, the Republican government established a new kind of institution for higher education, the *Ecole Polytechnique* that would provide a model for engineering educational institutions both in France and throughout Europe and the rest of the world, perhaps especially in the "new world" of the United States (cf. Jakobsen et al. 1998).

The polytechnical model was based on the idea that mathematical theory and general principles of science would form a foundation on which to transform technicians into civil servants. Headed by Gaspard Monge, a mathematician, the *Ecole Polytechnique* prepared engineers to take on the task of creating a new scientific society in which reason would replace religion as the basis for social order and authority. It was at the *Ecole Polytechnique* that Auguste Comte would develop his positive philosophy in the 1830s, and in the course of the nineteenth century, other institutions were later established on the polytechnical model in particular sectors, such as mining and agriculture, applying the facts of the positive sciences to the construction of the technological artifacts and artifactual systems of modern society.

In Britain, engineering education took a very different form (Smith and Whalley 1996). Even though there were mechanics institutes and so-called polytechnical schools established in the nineteenth century, they remained separate and inferior in status and prestige to the universities until well into the twentieth century, largely because of the very different meaning or perception of engineering in Britain:

> "Engineer" was a loose category that covered all sorts of practical men, from great entrepreneurs to humble technicians. "Rule of thumb" had served British industry well in the nineteenth century and was hard to unseat. Starting with the establishment of the Imperial college in 1907, serious efforts were made to overcome a perceived lack of scientific competence in British industry. These efforts were, however, subject to what might be termed the academic bias of British culture. To be attractive on the job market, the engineers had to comply with the gentlemanly lifestyle ideals of the hegemonic Oxbridge liberal education. The English academic engineers therefore generally chose to call themselves scientists rather than engineers. British twentieth-century engineering education became grossly dualistic.
> (Jakobsen et al. 1998, p. 106)

In addition to the specific character of engineering education and the perception of engineering as practical work, the British system of accreditation differed from the systems created in Germany and France, which dominated continental Europe. In Europe, government committees defined the qualifications of engineers through their educational programs. The British system of accreditation emphasized practical skills and engineering experience, and it also supported the idea that engineering competencies were of a different nature than the academic qualifications given by universities.

In Germany and in the Scandinavian countries, a third model or form of engineering education emerged in the course of the nineteenth century: *technische hochshulen* (renamed *technical universities* in the twentieth century) (Gispen 2002). These institutions combined education in natural science with what started to be called more specific, laboratory-based instruction in what started to be called the technical or engineering sciences. A variety of technical universities developed in Germany and the Scandinavian countries in the course of the nineteenth century, based on the idea that engineering contributed to the broader culture and the cultivation of the mind (cf. Hård 1998). Some of these theoretically trained engineers contributed to the rise of new industries following inventions in chemistry and electronics. However, in the nineteenth century, the practical engineers still dominated industrial development. Even in Germany where the laboratory training at universities was initiated and supported by the creation of research and development facilities in larger corporations, the contribution of engineers in industrial innovation came mostly from their practical experiences and systematic experiments and only in small part from theoretical, science-based knowledge.

Until well into the nineteenth century, technological development mostly relied on practical approaches in the crafts and the proficiency and experience of skilled technicians (cf. Lilley 1973). Development and production was characterized by practical approaches, trial and error, and a great deal of experience, intuition, and working knowledge about materials and mechanisms. Since the late nineteenth century, scientific approaches added a new element – what has been called innovation – to technological development and economic production. Systematic experimentation and the integration of ideas and methods of "scientific management" and management science into engineering increased the range and rapidity of development processes considerably. Still, in many fields of engineering, practical craft-like approaches could not be completely supplanted. As such, both approaches have continued to coexist, and in the course of the twentieth century, a more synthetic perception of engineering as technological innovation grew in importance in many fields, particularly in the newer, more "science-based" branches of industry. Rather than being either primarily theoretical or primarily practical, the engineer, according to this perception, became a synthesizer, developing new technology by combining theoretical and practical knowledge in new sites or what have come to be called "contexts of application," both at universities and in private companies (cf. Gibbons et al. 1994). In recent decades, particularly in such "technoscientific" fields as biotechnology and nanotechnology, engineering has come to be seen as a process of "hybridization" connecting different communities of practice, or fields of knowledge (cf. Jamison and Mejlgaard 2010).

Different Forms of Knowledge

The different approaches to engineering are based on fundamentally different and not easily exchangeable forms of knowledge, both in terms of explicit knowledge, derived from science, and tacit knowledge, derived from practice (cf. Polanyi 1958). The coexistence of science-based and practice-based forms of knowledge – and the emergence of a third, more synthetic form of knowledge in the course of the twentieth century – has led to significant tensions in engineering education, in terms of curriculum design and organization. How much scientific knowledge and how much practical experience should be included in the different engineering educational programs – and what kind of knowledge is required of the teachers?

The German pioneer in engineering design and long-time professor at the Polytechnical School in Karlsruhe Ferdinand Redtenbacher provided a diplomatic compromise in his textbook from 1852 (Redtenbacher 1852). According to Redtenbacher, technical problems may be solved either way, with a scientific approach or with a practical approach. Redtenbacher considered a mixture of both approaches to be the most effective, but did not specify how much science and how much practice a good education should include.

Only a few decades later, another fundamental tension became obvious. The institutional autonomy of engineering education in technical universities professionalized education and greatly increased the standards of learning compared to a practical education in the workshop. At the same time, a distance between the place of education and the workplace appeared which made it harder to shape engineering education according to professional needs. This distance mattered all the more, because teachers and professors now became removed from their original professional location, the engineer in industrial practice, while they successfully created a new profession, the engineering professor, with its own culture and set of norms and values. Though most teachers had a strong basis of experience in industry, from which they profited in their educational activities, a long physical absence from the original industrial workplace and the more reflective and autonomous culture in academia left their mark. A famous example is the powerful successor of Redtenbacher in Karlsruhe, Franz Reuleaux. In his early years, Reuleaux endorsed a combination of practical and theoretical education much as his teacher had done. About a decade later, he forcefully attempted to make engineering much more of an autonomous science and devise scientific methods suitable for solving whatever kinds of technical problems (cf. Reuleaux 1875). Engineering education, he contended, needed to become more scientific but scientific in a new way. What Reuleaux and others began to articulate in the late nineteenth century was the idea of a specific technical or engineering science (cf. Heymann 2005).

Reuleaux was not the only engineering teacher aspiring to a higher scientific status of the engineer. Engineering education at technical universities had reached a much higher degree of theoretical sophistication compared to Redtenbacher's times. This tendency caused significant irritation in parts of industry and among a younger generation of university professors. In the 1890s, a ferocious debate on the status of theoretical and practical education broke loose, the famous theory-practice debate (cf. Heymann 2009). More practical-minded professors like Adolf Ernst, Technical University Stuttgart, or Alois Riedler, Technical University Berlin, fiercely criticized colleagues like Reuleaux, refused their style of education, and praised the value of practical experience. The controversy continued for a whole decade and was finally resolved by introducing laboratories at the technical universities. The general issue, however, persisted and resurfaced in a number of debates throughout the twentieth century.

The practice-theory debate included a second highly debated issue, namely, the question who should teach mathematics to the engineering students. The mathematics courses had for years been given by mathematicians, but engineers increasingly complained about the high level of abstraction and the theoretical focus in these courses. Mathematicians had their own ambitions in and ideas of mathematics. The way many of them taught mathematics had only little to do with the demands of the engineers. This debate caused significant changes in mathematics teaching at many universities. More applied mathematics was favored, theoretical mathematics strongly reduced, and mathematics teaching often taken over by engineers. This conflict, however, exemplifies a more general tension in engineering education. Any engineering education comprises a significant degree of multidisciplinarity, mathematics only being one example of a needed additional discipline. Any teaching of disciplines other than engineering raised the question, who should be the teacher, a specialist in the discipline or an engineer with special competence in it?

Undoubtedly, new forms of knowledge production based on scientific methods led to a quick increase of engineering methodologies and knowledge. Technical schools and universities proved to be efficient institutions in teaching engineering knowledge, but continuously had to negotiate and adapt their curricula. Accelerated technical change permanently produced a tension between accumulating technical knowledge on the one and established and proved courses and forms of teaching on the other. A simple integration of new knowledge into curricula repeatedly led to problems of curriculum congestion and overload. But how could the curriculum best be rearranged to deal with new challenges? Which parts can be shortened or removed, and which parts should remain untouched? Such questions constantly mattered and could not easily be resolved. Factual arguments, historical contexts, as well as the social authority of fields in question played a significant role.

In the twentieth century, technical universities increasingly adapted to scientific and technological change and the growth of knowledge by way of differentiation of the education. Conflicts could at least partly be solved by an increase of the number of education programs and by broadening the range of optional specialties. However, the tensions that we have discussed in this chapter have continued to exist and caused considerable debate at various times, even though these debates may not have been as visible and vociferous as the practice-theory debate of the 1890s. The differentiation of engineering education ran across the same range of problems: How much science and how much practice should be taught in any of these special engineering fields? How can the institutional distance from university to the real world be successfully bridged and an efficient transfer of knowledge facilitated? Who should best teach special disciplines and in what way? How can a congestion of curricula be avoided without making engineering education too specialized and narrow?

Conclusions

The point of departure for PROCEED (Program of Research on Opportunities and Challenges in Engineering Education in Denmark) is the recognition that engineering and engineering education faces rather different sorts of challenges in the contemporary world. On the one hand, there is the overarching sustainability challenge, the need for engineers and engineering education to relate to the problems brought to light in the debates about environmental protection, resource exploitation, and climate change. Secondly, there are societal challenges, due to the use of science and technology into ever more aspects of our social interaction and forms of communication, not least due to the growth in production and consumption of the so-called information and communication technologies, especially computers, mobile telephones, and the Internet. And finally, there are the more internal challenges stemming from the emergence of what have been termed technosciences and, with them, the need for combining skills and knowledge and theory and practice in research work as well as in engineering education.

As we investigate the ways in which engineering educators have responded to these challenges, it will be important to place those responses in relation to the historical tensions that we have discussed in this chapter. The different approaches to engineering education that have developed in Europe tend to pull the responses into different directions. "Theory-driven" institutions and educators tend to respond to the challenges by reaffirming the importance of basic scientific knowledge. "Practice-driven" institutions and educators, on the other hand, tend to respond to the challenges by calling for more market-oriented skills and forms of training. What seem to be missing in many, if not most, institutions of engineering education are responses that are more comprehensive and include both practical and theoretical components to foster a more hybrid competence on the part of engineers to be.

An important focus of our research program is on the role that nontechnical or contextual knowledge plays in the various response strategies. In the theory-driven responses, contextual knowledge tends to play a marginal role consisting, at best, of instruction in theory or philosophy of science and/or engineering ethics, without changing the fundamentally theoretical orientation of the engineering curriculum, which continues to be based on mathematics and the natural and physical sciences. In the practice-driven responses, contextual knowledge tends to take the form of courses in marketing, entrepreneurship, creativity, and/or innovation studies "added on" to the primarily technical and practical curriculum. What seems necessary is to develop new programs in engineering education that integrate contextual knowledge – and, in particular, knowledge about the environmental, societal, and internal challenges facing engineering in the contemporary world – in a more substantive and meaningful way into the hard core of the engineering curriculum.

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Chapter 12
Socio-technical Integration in Engineering Education: A Never-Ending Story

Steen Hyldgaard Christensen and Erik Ernø-Kjølhede

Abstract The introduction of theory of science in Danish engineering education may be seen as an exemplary attempt to integrate socio-technical and contextual competencies into bachelor's engineering degree programmes. In this chapter, we set out to investigate in what way boundary definition and demarcation between technical text and social context have influenced the process of introducing and implementing theory of science into professional engineering bachelor's degree programmes. To set the stage, we first discuss how contextual issues and socio-technical competencies have been incorporated in accreditation criteria for first-cycle engineering degree programmes in the United States and Europe and some of the impediments for responding in engineering education. Second, we give a brief account of the rationale for implementing theory of science into Danish professional engineering bachelor's degree programmes. Third, we discuss our findings from an institutional example: a longitudinal case study carried out at Aarhus University, Institute of Business and Technology from spring 2007 to fall 2010.

Keywords Dialectics of boundary definition • Socio-technical competence • Contextual knowledge • Theory of science • Contested area • Translation process • Discursive strategies

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Introduction

The importance of incorporating contextual issues and developing socio-technical competencies in engineering education has been widely acknowledged in the engineering education community in Australia, Europe and the United States. High-quality engineering design requires understanding of how the engineered artefact interacts with individuals, society and the environment, both natural and manmade. In the US, the ABET EC 2000 criteria (www.abet.org) for accrediting engineering programmes incorporate context in two out of eleven programme outcomes (a–k) under criterion 3. The two context-related outcomes to be achieved by first-cycle engineering students are (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' and (h) 'the broad education necessary to understand the impact of engineering solutions in a global, economic, and societal context'. In the European EUR-ACE accreditation framework (Document A1-en Final 17 November 2005, Document C1-en Final 17 November 2005), context is incorporated as one outcome out of five under the heading 'Transferable Skills'. First-cycle engineering students are expected to 'demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice'. In Denmark, Executive Order No. 527 of 21 June 2002, from the Danish Ministry of Education, ordains inclusion of contextual concerns as one outcome out of five. Students graduating from professional engineering degree programmes should thus be able to 'plan, realize and control technical plants, and in doing so, include societal, economic, environmental and work environmental consequences in the solution of technical problems'. As it appears both in the EUR-ACE transferable skills criterion and the Danish executive order, there is a clear resonance with the American EC 2000 programme outcomes mentioned above. A common feature in all three sets of outcome and goals is that emphasis should be put on increasing the *breadth of problem scoping* (Kilgore et al. 2007) to embrace both local and global contexts when engaging in a design task.

However, contextual concerns defined in the US EC 2000 outcome (c) as an injunction to engineers to increase the breadth of problem scoping are but one out of a broader range of socio-technical competencies to be acquired by first-cycle engineering graduates. In the EC 2000 criterion 3 (see below), no less than five (d, f, g, h, j) out of eleven outcomes are socio-technical competencies required of first-cycle engineering graduates. Outcome (i) and to some extent also outcome (j) cannot be said to be socio-technical competencies in a narrow sense. They should be interpreted as an injunction to engineers to currently update and develop their knowledge, skills and competencies. However, all six outcomes below relate directly to liberal education (Ollis et al. 2004):

(d) Ability to function on multidisciplinary teams
(f) Understanding professional and ethical responsibilities
(g) Ability to communicate effectively
(h) Understanding impact of engineering solutions in a global and societal context
(i) Ability to engage in lifelong learning
(j) Knowledge of contemporary issues

Acquiring these socio-technical competencies is aimed at enabling students to focus on the general perspective and thus to contemplate their actions and their future profession in the larger context.

The broad education requirement as formulated in the EC 2000 criteria 3 under outcome (h) above is thus focused more broadly on the consequences of technology. The meaning of context here is different from outcome (c). The aim of outcome (h) is to incorporate contextual knowledge as background knowledge related to the relationship between science, technology and society. One way to interpret outcome (h) would be to see it as an STS requirement. Considerations of the impact of engineering solutions in a global, economic, environmental and societal context therefore incorporate a broad variety of strategies and approaches. Since context is a dialectical concept, perceptions of boundaries between technical *text* and social *context* differ both among engineers and non-engineers. This observation is equally valid for the EC 2000's outcomes (c) and (h). Boundaries between *the technical* and *the social* are not stable entities, neither in engineering education nor in engineering practice, but are amenable to reflection, negotiation and change over time (Bucciarelli et al. 1997; Faulkner 2000, 2007). Contextualization thus unfolds its inherent dialectic in the realm between *is* and *ought* both in engineering practice and in education. In engineering education, the dialectic of boundary definition may be highlighted by the two fundamental questions: What is engineering for? What are engineering studies for? (Downey 2009)

The introduction of 'theory of science' in Danish engineering education may be seen as an exemplary attempt to integrate contextual issues and socio-technical competencies into engineering bachelor's degree programmes in much the same way as defined in EC 2000 outcome (h). However, since the 2000 decision to introduce theory of science, this curricular novelty has given rise to a good deal of hesitation, resistance and controversy resulting in a considerable delay in its implementation (Christensen and Ernø-Kjølhede 2008, 2009). A possible explanation for the hesitation and in some respects resistance lies at an epistemological level. The dominant identity of engineers as 'problem solvers' has been moulded upon an epistemological distinction in engineering curricula between technical core and the non-technical periphery. The technical core/non-technical periphery distinction has had the consequence that knowledge hierarchies have emerged, which in many ways act as barrier mechanisms for development of socio-technical competencies. Usually, attempts to develop such competencies are relegated to the non-technical periphery as add-on components to an already overcrowded curriculum (Downey et al. 2007).

Hybrid engineering degree programmes, however, are interesting exceptions with different epistemologies which to some degree should make it easier to overcome epistemological barrier mechanisms. We therefore examine both a purely technical and two hybrid engineering degree programmes in our longitudinal case study below.

In many ways, theory of science has been a challenge to engineering identity. Hence, outcome and approaches have been very different among the Danish engineering education institutions (Christensen and Ernø-Kjølhede 2008, 2009). Before we embark on an account of the translation process that theory of science went through to gain legitimacy at our institute, let us very briefly look into what initiated the discussion on introducing theory of science in engineering education in Denmark (for a more comprehensive account, see Fink 2001; Christensen 2003, 2005; Christensen and Ernø-Kjølhede 2008, 2009; Hussman and May 2009).

The Struggle for the Soul of Engineering: Four Discursive Strategies to Tackle the Implementation of Theory of Science into Professional Bachelor Engineering Education

In 2000, theory of science became a compulsory curricular element in all bachelor's degree programmes in Denmark. This curricular novelty was intended to replace a previous Danish university tradition of offering what was called *philosophicum* or *studium generale* courses intended to provide a general understanding of scientific work and specialization. Contrary to that, theory of science was meant to be a platform for specific reflections on professional identity related to the following: (1) the objects, theories and worldview of the professional field, (2) the relationship to other professional fields and disciplines and (3) the relationship between professional fields and society (Christensen 2005).

The new curricular ingredient was expected to be fully implemented by 2004. The aim of theory of science was laid down in a letter to higher education institutions from the Danish Government in 2000. The letter stipulated that for all degree programmes both academic and professional:

> Students should be offered an opportunity to qualify their professional specialty by seeing it in a broader and more general perspective, and that 'The content of this curricular component must correspond to its purpose, namely to ensure correspondence between professional concerns and relevant concerns of a more general nature'.
>
> (Ministry of Education 2000)

In 2006, The Danish Evaluation Institute (EVA) formulated the following accreditation criterion (criterion 15 out of a total of 40 accreditation criteria) only for professional engineering degree programmes: 'Research methodology and theory of science must be part of the professional degree program in order to enable students to follow and apply R&D results in their field of specialization' (Danmarks Evalueringsinstitut 2006, 2008). It is noteworthy here that both research methodology and theory of science are made a compulsory requirement in order to achieve accreditation of professional engineering bachelor's degree programmes. Three additional criteria (9, 12 and 16), which together with criterion 15 were defined as 'central criteria', stipulate requirements for R&D underpinning of professional engineering degree programmes and their knowledge base:

> Criterion 9: Easy access to and integration of knowledge about research and research results related to the specific field of the degree programme should be provided through collaboration with universities and/or sector research institutions.
>
> Criterion 12: The knowledge base of professional training must embrace results from both Danish and international R&D and experimental work.
>
> Criterion 16: Professional training must integrate results from national and international R&D and experimental work relevant for the profession and well suited to serve as exemplars for the development and application of new professional knowledge.

Today, theory of science has been fully implemented in all engineering bachelor's degree programmes, whether professional or academic, in Denmark. Approaches have been different but nevertheless, theory of science has now found a place in engineering curricula. An overall assessment of the outcome has, however, not yet been carried out.

What concerns us here is the chain of reaction between the general governmental stipulations put forwards in 2000, the specific accreditation criteria put forwards by the Danish Evaluation Institute (EVA) in 2006 and the process of institutional implementation taking place from 2001 onwards. An indication of doubt, hesitation and controversy regarding institutional response strategies on the part of engineering degree programmes is that the implementation process in general has been characterized by a considerable delay compared with the original goal that theory of science should be implemented by 2004. As the initiative did not originate in the engineering community but was imposed, both internal and external constituencies became entangled in a struggle over the soul of engineering. Theory of science thus became a *contested area* and went through a *translation process* where discursive strategies were mobilized by relevant constituencies to safeguard or redefine boundaries between the technical and the social in engineering education (Christensen and Ernø-Kjølhede 2008, 2009).

Based on previous research by the authors (2008, 2009) and based on a reading of a number of other sources (mentioned below), we argue that it is possible to construct a typology of responses or discursive strategies that stakeholders might adopt when faced with challenges that seek to alter the balance and the boundaries between the social and the technical. And clearly, engineering education is a sort of battleground where the contested area is fought out. We believe that four basic discursive strategies may be and have been mobilized by stakeholders in the Danish case:

1. *The discourse of Bildung* addressing the engineer as a human being (For the German origin of the notion of Bildung, see, e.g. Ringer 1969; Gispen 1989. For US connotations, see, e.g. Florman 1987, 1996. For the Danish discourse of Bildung, in which theory of science in engineering became embedded, see, e.g. Børsen Hansen et al. 2000; Johansen 2002; Sjöbjerg 2005; Christensen 2003, 2005; Christensen et al. 2006)
2. *The discourse of business and commerce* addressing the engineer as a businessman (See, e.g. Goldman 1991; Johnston et al. 1996; Holt 2001; Undervisningsministeriet 2005, 2006; The Danish Government 2006)

3. *The discourse of engineering science* addressing the engineer as an innovator and researcher (See, e.g. The Danish Evaluation Institute (EVA) in 2006, 2008; Millennium project 2008; The National Academies 2009)
4. *The discourse of engineering practice* addressing the engineer as a professional problem solver in different professional roles such as, e.g. the environmental consultant, the designer, the system builder, the staging director and the model developer (See, e.g. Bucciarelli et al. 1997; Beder 1997, 1999; Jørgensen 2003; Sheppard et al. 2009)

In the influential formulation of Bourdieu (see Nash 1999), what was at stake in the debate on how to implement theory of science in Danish engineering education was the formation of the *habitus* of engineers. In Bourdieu's definition, habitus implies a set of habits and dispositions that have been inculcated through a social acculturation process: 'The habitus as the word implies, is that which one has acquired, but which has become durably incorporated in the body in the form of permanent dispositions… the habitus is a capital, but one which, because it is embodied, appears innate' (Nash 1999). *Capital* as we use it here is thus related to the habitus of engineers and refers to the cultural and social capital broadly defined that engineers acquire through their education. Historically, especially, the discourse of Bildung which relates to Bourdieu's notion of cultural capital has created a climate of controversy across the liberal arts-engineering divide, as this discourse was and still is alien to many engineers and largely seen as a misguided effort to reform engineering education. Moreover, the discourse of Bildung was implicitly seen as a proxy for the cultural capital of an elitist Mandarin culture (Ringer 1969; Gispen 1989) which was aptly described by C. P. Snow in 1959 in his influential essay '*The two cultures and the scientific revolution*' (Snow 2001). As will appear from the analysis below, at our institute particularly, discourses 2 and 4 appear to have had formative influence on the positions taken by engineering faculty members in the process of implementing theory of science in professional bachelor engineering degree programmes.

Balancing the Social and the Technical: An Institutional Example of the Implementation of Theory of Science into Professional Engineering Degree Programmes

The contention is that our institute provides a site that is well suited for a study of the process of implementation of theory of science as a proxy for the discussion of text and context in engineering education. The reason being that our institute at the professional bachelor's level offers both two hybrid engineering programmes mixing technical and social science (Global Management and Manufacturing and Business Development) and one purely technical engineering degree programme (Electronics).

We have investigated the *translation process* of the theory of science requirement into specific course programmes as a longitudinal study. We have studied teaching plans, required readings and lists of literature in the 3 professional engineering bachelor's degree programmes at our institute, and we have gathered empirical data from engineering faculty members. Our research design consists of both *ex ante* and *ex post* data collection. The *ex ante* data were collected in 2007 and 2008, while theory of science was in the preparatory phases and not yet fully implemented in the degree programmes. For the collection of the *ex ante* data, we used two methods, an anonymous questionnaire survey carried out in 2007 and semi-structured focus-group interviews carried out in 2008 in three focus groups with three faculty members of each degree programme[1] (this *ex ante* research was partly published in Christensen and Ernø-Kjølhede 2008, 2009). By 2010, theory of science was fully implemented in the bachelor's engineering degree programmes making it possible to carry out an *ex post* study. The method applied for this *ex post* study was semi-structured interviews with the two teachers responsible for theory of science in the bachelor's engineering programmes plus content analysis of course descriptions, teaching plans, required readings and lists of literature. In the following, we give a brief summary of our findings starting with the *ex ante* study drawing on data collected in 2007 and 2008 and published (in part) in 2008 and 2009.

Pre-implementation Expectations of and Attitudes Towards Theory of Science Among Teaching Staff

As theory of science is a new subject in the Danish engineering curriculum, it was, at the beginning of its implementation, not yet well established in the minds of engineering faculty members at our institute. A comment written on the back of a questionnaire filled in by a respondent may serve as an illustration: 'The issue (theory of science in engineering) and the way in which it is presented is some galaxies away from my world for which reason I haven't answered a number of questions. A more extensive oral presentation might have been able to compensate for my engineer's handicap'.

Below, question 11 out of a total of 16 questions is meant to highlight issues of relevance for theory of science for engineers and to measure attitudes among engineering faculty members towards these issues. Question 12 is intended to measure perceptions among engineering faculty members regarding the relative importance of theory of science and research methodology.

As responses to question 11 are not binding in the sense that they would have formative influence on the implementation of theory of science, they are more likely to measure perceptions of what engineering faculty members would think would be

[1] The questionnaire was distributed to 35 potential respondents comprising the entire full-time teaching staff of our institute's three professional bachelor's engineering degree programs in electronics, business development and global management and manufacturing (part-time teachers not included). 26 respondents filled in the questionnaire – one respondent however only partly. 16 respondents are engineers, 4 hold degrees in business studies, 5 in science and 1 in psychology.

Question 11 Please indicate on a scale from 1 to 5 the relevance of the below-mentioned issues for theory of science courses in engineering education

Dimension	A	B	C	D	E	F	G
Scale	Engineering roles and identity	Engineering culture and norms	The design process as a technical and social process	Knowledge generation and forms of knowledge in engineering work	The importance of technology and its impact on society	Ethical problems in engineering	Requirements of interdisciplinary and intercultural collaboration
1. Irrelevant	2	2	0	0	0	2	0
2. Minor relevance	4	7	2	2	0	1	1
Subtotal X 1+2 opponents	***6***	***9***	***2***	***2***	***0***	***3***	***1***
3. Some relevance	9	7	8	9	4	6	9
4. Relevant	7	8	10	8	12	12	6
5. Very relevant	3	1	5	6	9	4	9
Subtotal Y 3+4+5 proponents	***19***	***16***	***23***	***23***	***25***	***22***	***24***
Total	25	25	25	25	25	25	25

Question 12 How would you evaluate the relative importance of research methodology and theory of science respectively?

Scale	Frequency
1. To learn research methodology is more important than theory of science.	17
2. To learn theory of science is more important than research methodology.	0
3. Research methodology and theory of science are equally important.	7
4. Neither research methodology nor theory of science is important.	1
Total	25

'nice to know' for engineers (chiefly, 'The importance of technology and its impact on society' and 'Requirements of interdisciplinary and intercultural collaboration'). However, responses cannot be said to measure perceptions of what engineers would think they would 'need to know'. By contrast, responses to question 12 to a greater extent measure perceptions of what engineers think they would 'need to know' (research methodology is clearly rated as more important than theory of science).

In our analysis of the data from the three focus-group interviews carried out with teaching staff, we were furthermore able to identify a number of recurring arguments of an ideal typical nature. We have termed these arguments regarding the need, rationale and scope of theory of science as follows:

1. The 'no need' argument. Illustrative quote: 'The type of engineer that we educate is supposed to work in a company. He should be able to put things together and make them work. He is not supposed to question philosophically what he is doing and why he is doing it'.
2. The 'instrumentalize it' argument. Illustrative quote: 'Taking professional engineering degree programmes which are not wildly academic as a point of reference, I think some of these abstract concepts, especially the methodological part of theory of science, simply may help the students to become better at solving problems'.
3. The 'split it up' argument. Illustrative quote: 'In my view it is not wise to make theory of science an independent module. Ideally it should be taught when needed in specific engineering disciplines or problem areas. In so doing, it would not have the negative side effect of increasing the pressure to remove vital engineering topics'.
4. The 'trade-off' argument. Illustrative quote: 'Which new topics should be incorporated and which ones should be removed? At the moment the curriculum is tightly packed… with courses which we have selected very carefully and which have proved their value in a company context. If additional courses are to be incorporated into the engineering curriculum they must relate to the engineering mode of thinking. They should not be constrained to merely philosophical reflections'.

These arguments taken together clearly serve to demarcate a boundary between 'nice to know' and 'need to know'. As shown above, our findings demonstrate a clear demarcation between the relevance of theory of science as 'nice to know' and research methodology as ‘need to know’. However, this boundary cannot simultaneously be interpreted as demarcating a boundary between ‘the technical’ and ‘the social’. As an illustration, a respondent argues, ‘A broader vision is needed. I firmly believe that to be able to cooperate with people with different educational backgrounds and participate in interdisciplinary and international collaboration we will have to learn to understand their norms and ways of framing and defining problems’. And another respondent comments that ‘we are not used to thinking along these lines. It has something to do with the engineering way of thinking. We do not seek knowledge merely for the sake of knowledge to be able to discuss it in the lunch room’. Moreover, to demarcate the Bildung and engineering science discourses, the discourse of business and commerce and the discourse of engineering practice are in large measure mobilized by teacher respondents; some examples are the following:

> Example 1. They [the companies] say that the project managers they need must have business talent. They should be able to negotiate the right price and be capable of establishing networks both internally and externally.

> Example 2. They [the students] simply live and breathe for the companies, in which they are hired and in which they work. I personally feel likewise.

> Example 3. Our students have a very good reputation indeed in the local companies: quite often we receive mail from companies that wish to hire our students or ask whether we have students who will complete their study within a short time in order to offer them employment. This quality stamp on our education therefore allows us to conclude that we currently teach our students the qualifications which are requested by companies.

The overall impression of our *ex ante* study was thus that respondents gave more weight to concrete research methodology as compared to the more general concept of theory of science. Further, the respondents attached more importance to theory of science supporting the engineer as a businessman and problem solver rather than as a cultivated scientist. As also reported in our 2008 and 2009 articles, respondents on the whole held positive expectations and attitudes towards the inclusion of theory of science in the curricula. It was widely believed that theory of science had a potential to help improve the study programmes. However, it should also be noted that the implementation phase had been remarkably long (6–7 years by the time of the survey) and that interviews reflected a good deal of hesitation and doubt as to *how* theory of science might be implemented in order to improve the studies and as to exactly which parts of the study programmes it might be able to improve.

Post-implementation Expectations of and Attitudes Towards Theory of Science Among the Teachers of the Subject

In this section, we examine how theory of science has been implemented in the three professional engineering bachelor’s degree programmes at our institute. Before embarking on this, it is necessary to briefly describe the epistemologies of the three programmes. Business development engineering (BDE) and global management and manufacturing (GMM) can be characterized as hybrid engineering degree programmes (combining social and technical science), and they differ from the third programme, electronic engineering, as the epistemological core/periphery distinction cannot be said to uniformly follow the technical core/non-technical periphery distinction. In GMM, it may even be argued that the epistemological distinction is one between the business core and the technical periphery. A GMM respondent in the focus-group interviews reported above thus observed that 'GMM could equally well have been positioned as a business degree program… focused on management and supply chain management'. In BDE, marketing, business creation and business knowledge are defined as the epistemological core. However, here the epistemological core also embraces technical issues which are seen as the basis for business creation. Among teacher respondents from electronic engineering, the epistemology is clearly moulded upon the technical core/non-technical periphery distinction for which reason a technical orientation clearly prevails. When therefore speaking of theory of science in these three engineering programmes, the crucial questions are the following: Theory of science and methodology for what? Business or technology? How much business and how much technology? And, can these concepts at all be separated?

We have carried out semi-structured interviews of one-hour duration with each of the two teachers responsible for theory of science at our institute, and we have made a content analysis of course descriptions, teaching plans, required readings and literature lists. In the spring semester 2009, 5 years after the year of implementation stipulated by the Danish government (2004), a new compulsory add-on course module was developed to be implemented in spring 2010. The workload of the course is equivalent to five ECTS (European Credit Transfer System) credit points, and in spring 2010, it was delivered (1) as a common course for students in electronic engineering and business development engineering at the sixth semester and (2) as a separate course for students in global management and manufacturing at the fifth or seventh semester.[2] The objectives of the course are defined as follows:

> The main purpose of the course is to give to the students a basic understanding of different approaches to problem-solving. Besides, the students are introduced to the relationship between scientific approaches and methods used to collect empirical information and data. The course also introduces students to professional cultures related to problem-solving and the conflicts and misunderstandings that may arise between the different perspectives. The students will also learn to assess alternative scientific approaches when defining solutions for specific issues.
>
> (Course description 20 November 2009)

Problem-solving in both engineering and business and inter-professional and intercultural collaboration are thus the central concerns in all three degree programmes. This is very much in line with the *ex ante* attitudes expressed by respondents above,

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[2] As formulations of objectives and main areas of content in the two course descriptions differ in length but not in substance, we have chosen to quote only from the course description for electronic engineering and business development engineering as this course description is more elaborate than the one for GMM.

and it would thus seem that faculty attitudes and discourses 2 and 4 above have been very influential in shaping the theory of science course module. The course content is focused on the following main areas (Course description 20 November 2009):

- Knowledge of various scientific approaches such as positivism, post-positivism, systems theory, hermeneutics and social constructivism
- Understanding of the consequences of scientific positions at ontological, epistemological and methodological levels
- Understanding of the consequences of scientific theory for the concrete use of methods in connection with the resolution of a concrete problem
- Understanding of the link between theory of science and the way a scientific article is organized and written
- Understanding of the link between different professions and their methodological approaches to problem-solving.

For electronic engineering students and BDE students, the subject is taught by a teacher with a PhD in sociology and with an assistant teacher trained as an engineer. In the course for GMM students, the subject is taught by a teacher with a master's degree in business. The courses are based on lectures, student presentations and case study-based exercises. The literature in the courses mainly draws on business and social research methodology.[3]

In the interpretation of data from the semi-structured interviews with the two teachers of theory of science, we follow a fourfold structure: (1) attitudes among engineering faculty members and students at the beginning when theory of science was introduced, (2) the proportion of theory of science/research methodology related to technical science, social science and the humanities or other fields in the course, (3) the competencies that theory of science courses are meant to create and (4) attitudes among engineering faculty members and students today.

According to both teacher respondents, they were facing three challenges at the beginning when theory of science was first introduced: (1) to be able to interact constructively with engineering faculty members to get their support for the internal marketing of the course to students, (2) to be able to convince engineering faculty members that theory of science could help engineering students improve both their problem-solving skills and their ability to reflect critically and (3) to position theory of science and research methodology as part of the epistemological core in engineering problem-solving in the three degree programmes. Below, the teacher of the common course for students in electronic engineering and BDE gives the following characteristic of the initial situation:

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[3] Examples of typical references are the following: Arbnor, Ingemar and Bjerke, Björn (1997). *Methodology for creating business knowledge*. Sage Publications. Bryman, Alan and Bell, Emma (2007). *Business research methods*. Oxford University Press, Oxford. Bryman, Alan (2004). *Social research methods*. Oxford University Press, Oxford, Guba, Egon and Lincoln, Yvonna S. (1994). Competing paradigms in Qualitative research. In: Denzin, Norman K. and Lincoln, Yvonna S. (Eds.). *Handbook of qualitative research*. Sage Publications, Neuman, Lawrence (2003). *Social research methods*. Allyn and Beacon Publishers.

> When I started I didn't see theory of science as the most fascinating subject to teach because of what I had heard… I really had to work hard to show that theory of science was not a threat to engineering students and faculty members… At the beginning faculty members were sceptical about me as I was seen as an academic (as opposed to a more practically oriented engineer. (inserted by the authors))… The engineering faculty members saw theory of science as something really academic… The students were told by engineering faculty members that theory of science is a boring subject… Engineering faculty members didn't try to make sense of it and adapt to this new curricular requirement.

The GMM teacher respondent characterizes both the initial and the present situations this way:

> As I see it theory of science is the glue that binds all the subjects in the engineering curriculum together… On the GMM program I have the feeling that the attitude of engineering faculty members towards theory of science is that they are not interested and that they really don't care about it.

The electronic engineering and BDE teacher respondent also notices that there is a difference in the readiness to accept different worldviews and approaches between electronic engineering students and BDE students:

> The readiness to accept that life can be different is higher in BDE than in electronic engineering… In electronic engineering the method is more rigid… In electronic engineering it is generally held that there is one right way and one right answer… Courses are not challenging students in the sense that they are confronted with different research paradigms and approaches… When they come to the course the BDE students are receptive to different approaches because they have seen the differences working in their courses.

Regarding the relative proportion between the more general theory of science component and the more specific research methodology component, the GMM teacher respondent comments:

> As the course is oriented towards practical application the main focus of the course is on methods and techniques… I would say 80% lies here which also makes it easier to sell the course to students… I would however not go so far as to suggest that Bildung should have no place in the course. In my course Bildung would amount to 20%.

The other teacher respondent comments that emphasis should be put on what is readily applicable in the engineer's toolbox and warns against too much emphasis on Bildung: 'If you design the course as a merely theoretical course with a focus on critical reflection and discussion after a while there would only be very few students left in the class'. Moreover, according to the electronic engineering and BDE teacher respondent, the proportion of research methodology related to technical science is 40%, social science 40% and the humanities or other fields in the course 20%. In GMM, the proportion is that 10% research methodology is related to technical science, 70% to social science and 20% to the humanities or other fields. Finally, regarding the various purposes that theory of science and research methodology are meant to support, the two teacher respondents unanimously carried out the following ranking (ranked by relative importance in the course):

1. The student's ability to solve concrete practical problems, be they commercial or technical in nature
2. The student's ability to collaborate with people who demarcate and define problems differently in a corporate setting

3. The student's ability to work in a scientific way both methodologically, theoretically and critically
4. The student's acquisition of a broad background of contextual knowledge – Bildung – related to the relationship between science, technology and society (STS)

As it appears, the ranking of the four purposes is in accordance with discourses 2 and 4 mentioned previously.

After completing the first common course for electronic engineering students and BDE students, the teacher comments that attitudes among engineering faculty members and students in BDE have changed positively, whereas attitudes among engineering faculty members and students in electronic engineering have remained sceptical as they were initially. This is a clear indication that the boundary between the technical and the social is drawn differently in hybrid engineering degree programmes and purely technical degree programmes illuminating a difference between heterogeneous and more 'mono-technical' engineering cultures. The teacher says it this way:

> The BDE students value the course because they can see that it makes them stronger… Presently both engineering faculty members and students see theory of science as a natural part of their study program… Among electronic engineering students and faculty members there is a more sceptical attitude as it is not so obvious for them that theory of science is relevant for them… Electronic engineering students didn't really take part in the course and they were not really able to see the use of it… because they so to speak work at the screwdriver level.

In GMM, attitudes among engineering faculty members have remained uninterested as they were at the beginning when the theory of science course was taught for the first time, 'they really don't care about it' as the teacher puts it. Students however are not negative towards the course but

> compared with the openness that I have experienced in introductory methodology courses at the first semester [in other degree programs] students are gradually socialized into a professional engineering culture which makes them less open in the final part of their study [where the course is taught]…However I have not experienced that engineering students are dissatisfied with my theory of science course.

We might therefore conclude that students from hybrid engineering degree programmes at our institute have attitudes towards theory of science and research methodology (as perceived by the teacher respondents) that are located along a continuum ranging from satisfied to not unsatisfied, whereas students from the technical degree programme are more sceptical as they cannot see the use of it and therefore find it hard to believe that it can help them in any way.

Conclusion

To be able to respond to the grand challenges of our time (The National Academies 2009) and to avoid engineering work declining into purely technical support vis-à-vis the threat from low-wage countries (Millennium Project 2008; Downey et al. 2007), it has been argued that there is a need for hybridization in engineering education

(Williams 2002; Jamison et al. 2011). 'Hybridization reflects the need for different communities to speak in more than one language in order to communicate at the boundaries and in the spaces between systems and subsystems' (Gibbons et al. 2005, p. 37). Moreover, Jamison et al. (2011) have argued that theory of science could be interpreted as an exemplary attempt to help develop a hybrid imagination in Danish engineering students:

> A hybrid imagination can be defined as the combination of a scientific-technical problem solving competence with an understanding of the problems that needs to be solved. It is a mixing of scientific knowledge and technical skills with what might be termed cultural empathy, that is, an interest in reflecting on the cultural implications of science and technology in general and one's own contribution as a scientist or engineer, in particular. It can be thought of as an attitude of humility or modesty, as opposed to arrogance and hubris, in regard to scientific and technological development, and for that matter, to any kind of human activity. A hybrid imagination involves recognizing the limits to what we as species and individuals can do, both the physical limits and constraints imposed by "reality" as well as those stemming from our own individual limits of capabilities and knowledge. As such, a hybrid imagination is often manifested collectively, involving collaboration between two or more people when it is not explicitly a part of a social or cultural movement.
>
> (Jamison et al. 2011, p. 4)

It would seem that such an endeavour is not an easy task. What has become evident from our longitudinal case study of the implementation of theory of science at our institute is that the degree of openness and readiness to acknowledge this new curricular component is varying in the three degree programmes both among engineering faculty members and students. Attitudes range from positive acknowledgement and indifference in the two hybrid degree programmes to scepticism and lack of acknowledgement in the more technical degree programme. It has also become evident that what engineering faculty members may say in an *ex ante* survey may differ from how they act when it concerns core aspects of their professional identity (the *ex ante* survey showed positive attitudes among faculty towards the implementation of theory of science, whereas the *ex post* interviews with the two theory of science teachers demonstrated that they experienced a good deal of scepticism or indifference among the very same faculty especially at the outset of the course).

The combined theory of science/research methodology approach that has been implemented at our institute is but one out of a broad variety of approaches that have been implemented in Danish engineering education. It seems that a viable approach has been found in the two hybrid degree programmes, whereas the approach in the electronics programme might be characterized as only a temporary *modus vivendi*. There appears to be no optimal and final solutions in implementing theory of science in engineering education but only temporary solutions reached by negotiation and compromise. The integration of socio-technical competencies therefore seems to be a never-ending story.

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Chapter 13
Tensions in Developing Engineering Design Competencies

Ulrik Jørgensen

Abstract Engineering design competencies and the role of scientific disciplines in engineering curricula form the background for this chapter. Engineering knowledge as produced in the context of engineering education at large is seen as the key to understanding the dominant strategies of machination in engineering practice. At the same time, there is a need to bring new perspectives to engineering design and to the understanding of engineering knowledge. The crowding of engineering education with an exploding number of new specialities and disciplines has rendered problematic the broad 'polytechnics' education prominent in the traditions of engineering education. While the idea that engineering is building on a natural science base is still dominant as the common model for the education and identity building of engineering, the growth in specialties and required competencies are blurring the claims by engineering schools and institutions of a common engineering identity. Social sciences and humanities primarily have functioned as an add-on to the rather diverse engineering curricula at the same time as new ways of understanding technologies as hybrids constructed through historical and situated actors associations have created a new ground for interdisciplinary integration. In design engineering education, these new types of knowledge have become foundational for their approach to technology.

Keywords Engineering design • Education • Competence • Practice • Science discipline

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Introduction

By the 1990s, basic questions had been raised in both the United States and Europe about the relevance of engineering education as it had developed since World War II. The issues included a lack of practical skills in modern engineering training, a mismatch between the needs of industry and the sciences being taught, and the actual analytical qualifications being awarded in engineering education compared with visions of engineers as creative designers and innovators of future technologies. With its emphasis on science and knowledge structured around technical disciplines, engineering education developed into an education of basically technically skilled cooperative workers rather than innovative and creative designers of technology for society. The knowledge and broad innovative capacity needed to produce creative design engineers able to cope with contemporary technological changes were seen as missing in engineering education.

Several educational initiatives have addressed these issues, outlining plans to reform engineering education. Some focus on the engineering curriculum or the pedagogy and learning modes employed; some develop completely new engineering programmes based on new technologies. Other initiatives combine business, management, and organisational understanding with engineering or alternatively emphasise the creative and design aspects of engineering.

Critical accounts by observers close to the situation point to the need for reform in engineering education (Williams 2003). Some critics seem confident in the achievements of engineers in society and argue for the continuation of a traditional science-based engineering curriculum (Vincenti 1990; Auyang 2004). However, they do not raise critical issues related to the social and institutional dependencies of technology. Engineering schools and professional institutions have supported the idea of a close relationship between science and technology by asserting that natural sciences form the core foundation of engineering. At the same time, contemporary developments in the natural sciences and engineering sciences have blurred the boundaries. New approaches to techno-science seem to be gaining ground as characterising the ties between modern science and technology, leaving neither one in a subsidiary role (Ihde and Selinger 2003). These new approaches recognise the role of technology as a contributor to scientific achievements and change the basic idea of nature and technology. A key question is whether these accounts are satisfactory in understanding and coping with contemporary problems in engineering education in relation to the demands on engineering practice at large.

Two basic elements are important to understand contemporary challenges to engineering knowledge and design practices. One relates to the demand for engineering competence and engineering solutions in industry and society. The other relates to the institutional developments in engineering schools and the role of engineering sciences in relation to objects of technology to be handled by engineers. The approach in this chapter will be to (1) identify historical developments in technology and its social embedding and the role of engineering institutions in this relation and (2) build a theoretical framework to better understand engineering knowledge and competence and how they challenge the role of education. The three following sections will outline tensions in the research and educational agendas of engineering institutions following the visions of engineering science and its controversial relationship to engineering practice and consequently the gap between engineering practice domains and engineering curricula. The subsequent four sections start with a new focus on engineering competence in order to present both the critique of engineering education and visions of new modes of learning and a design focus in engineering competence building.

A Science Base for Engineering

In order to understand today's situation, we must consider one of the most important historical changes in engineering education – the construction of a science base for engineering. This development resulted partly from the increase in public and military funding of engineering research during World War II, partly from attempts to develop a more theoretically based foundation for engineering. The endeavours to establish a science base for engineering created an elite group of theory-oriented universities and technical schools of higher education in both the United States and Europe (Reynolds and Seely 1993).

Until the early twentieth century, a rather deep gap existed in engineering curricula between science classes based on high degrees of mathematically formalised knowledge and the more descriptive and less-codified technical subjects. Controversies resulted in positioning technical sciences as secondary, or applied, in relation to the natural sciences. Technical universities, at least in Europe, were restricted from giving doctoral degrees and addressing scientific matters without the support of university faculty versed in the natural sciences. However, the new era of expanding technical sciences lessened these controversies because of its increased focus on innovation and awareness of the close interactions between specific areas of science and technology.

A leading institution in this change in the USA was the Massachusetts Institute of Technology (MIT). Although engineers made significant contributions during World War II, the success of the Manhattan Project put physicists in the spotlight. Savvy engineering leaders recognised that the path to prestige lay in a closer emulation of scientists. In Europe, this orientation towards a scientific basis for engineering already had a long tradition in the intellectual environment around the elite institutions, especially in France and Germany. The post-war tendency towards formalisation of science councils and large government-sponsored research programmes centred on the peaceful utilisation of technologies developed during the war and spurred a dramatic increase in research at technical universities and a change in the methods of teaching engineering.

Sponsorship of fundamental studies in a variety of areas supported the trend away from practice-oriented research and education resulting in critique from industry (see, e.g. Cohen and Zysman 1987; Dertouzos et al. 1989). Successes in fields such as high-speed aerodynamics, semiconductor electronics, and computing confirmed that physics and mathematics, conducted in a laboratory-based environment, could open new technological frontiers. Military research during these years also tended to focus on performance – increased power, higher altitudes, and more speed – goals that were conducive to scientific approaches (Reynolds and Seely 1993).

The post-war decades saw the rise of systems engineering and thinking as broadly applicable engineering tools (Mindell 2002). Systems sciences that include control theory, systems theory, systems engineering, operations research, systems dynamics, cybernetics, and others led engineers to concentrate on building analytical models of small-scale and large-scale systems, often making use of the new tools provided by digital computers and simulations (Hughes and Hughes 2000). Some within engineering even found that these tools might finally provide the theoretical basis for all engineering that goes beyond the basic principles provided by the natural sciences.

Changes in the foundation of engineering education, with the expansion of science-based technical disciplines, also led to changes in the curricula of traditional vocational schools of engineering. Though with different names, 'polytechnics' in the United Kingdom, 'fachhochschulen' in Germany, and 'teknika' in Denmark shared common characteristics in recruiting students from groups of skilled technicians and supplementing their training with a theoretical education while maintaining a focus on industrial practice. As a result, the schools inherited the experience-based and practical knowledge and skills of students who had previously worked as apprentices in construction firms, machine shops, and industry. During the 1960s, the curricula of these technical schools were expanded. Typically, these changes included improvements in mathematics and natural sciences by copying the science base from engineering universities.

At the same time, the decline in the apprenticeship training of craftsmen and skilled workers began to undermine the recruitment lines of the polytechnics (Lutz and Kammerer 1975). While this type of engineering education was well supplied by the traditional, smaller craft-based industries, the increasing size of industries led to a change in the ways the workforce was trained, resulting in increasingly specialised machine-shop skills. Fewer candidates had the necessary broad skills and apprenticeship training required by the engineering schools. Consequently, the schools were forced to establish other recruitment systems to survive, leading to a complete reversal of the basis for recruiting students during the 1990s.

As a result, the overall trend towards a more science-based curriculum becomes dominant in all parts of engineering education.

Transfers from Engineering Practice to Scientific Discipline

The structure of many engineering institutions still shows the remains of the big four in engineering – civil, mechanical, chemical, and electrical – that date back to the nineteenth and early twentieth centuries. Electrical engineering was the exception almost from its origins in the early twentieth century. In this engineering discipline, the relationship between theoretical teaching and industrially developed technologies was closer than in other engineering domains.

Yet today, many engineering departments still have their core activities defined by technical disciplines, such as mechanics, energy systems, electronics, chemistry, building construction, or sanitary and civil engineering. Many of these disciplines were related to specific problems and industries in their founding years, but as the demand for science-based research and teaching became prominent, the original roots to practice and industry declined in significance. With the changing demands, more abstract courses defined by new scientific approaches and specialised fields were developed.

In the course of history, many engineering disciplines have developed from what could be called an encyclopaedia stage, dominated by descriptive representations of technological exemplars, into a more abstracted and theory-based scientific stage (Latour 1987; Jørgensen 2003). This latter stage adds the strength of applying model descriptions, including mathematical representations and topic generalisations. However, in the transformation process, concrete experiences and practice-based knowledge, embedded in specific technical solutions, has often been lost. Consequently, the transition represents a movement from scattered collections of representational exemplars to more complete representations of the technologies in question, documented by constructed theories and models. At the same time, the transition represents a movement away from the engineering practice and experience needed to make technology functional (Gibbons et al. 1994).

Contemporary tensions in engineering education are spurred by the diversity of modern technologies. The applications of these diverse technologies throughout society require increasing differentiation in the education of engineers. The diversity presents new challenges to the sense of unity, identity, and standardisation of professional preparation in engineering institutions. Despite the complexity and multiplicity of technologies, institutional unity and its manifestation in a common engineering core curriculum have so far been successfully maintained by the engineering profession and by elite engineering universities.

Nevertheless, the policies of identity formation and the creation of a homogeneous image of engineering are issues that need to be taken seriously, both in historical accounts and in contemporary reform initiatives. Engineering identity plays a vital part in both arguments for and against educational reform in negotiations about engineering educational reform. The battle over engineering identity is closely linked to the significant role assigned to core disciplines of natural and technical sciences as defining the common ground for engineering, the add-on role of non-technical topics as well as the controversies over the relationship between science and practice.

Engineering Domains Versus Discipline

Early in the twentieth century, the idea that engineers have societal responsibility and are the heroic constructors of the material structures of modern society was being supplanted by a less heroic and more mundane image of engineers as the servants of industry. This image of engineering reflects a reduction in the influence of engineers on the direction and content of technological innovation and supports the positioning of engineers in a less influential and subordinate role in their attempts to promote business interests, which is maybe closer to engineers' self-image in contemporary society. The description of an engineer's contemporary competencies might include the following: 'scientific base of engineering knowledge', 'problem-solving capabilities', and 'adapt knowledge to new types of problems'. The focus is more often on problem solving and less on problem identification and definition (Downey 2005).

Engineering problem solving most often is related to intentional goals, where the job is to handle a practical situation either by constructing an artefact, modifying existing solutions, or identifying the reasons for certain failures. The aim is not, like in most scientific endeavours, to establish a deeper and more theoretical substantiated understanding of the problem in focus but to produce working solutions and test them in accordance with existing knowledge of performance and eventual risks. It is the solution to the present problem that is important and independent of eventual limitations to the existing knowledge; the practical imperative is to identify a solution (Jakobsen 1994).

Engineering problem solving is characterised by the organisation and resources framing the situation (Noble 1977; Roe-Smith 1989), the heterogeneous character of the involved and relevant knowledge (Hård 1994, 1999), and the hybrid (Latour 1993) – and even sometimes complex – character of the resulting solutions. Problem solving involves knowledge from different domains of engineering practice and knowledge from different disciplines as well as combining these with practical experience and existing routine solutions. By tradition, there has been a tendency to emphasise knowledge produced by the natural and technical sciences as the most important for engineering, while contributions from other disciplines are taken into account more in line with practical experiences. This contradicts the experience from many studies of technology demonstrating that the objects of engineering practice very often are hybrids synthesising knowledge coming from both the sciences and the social context and the users' (involved actors') association of meaning assigned to the intended functional and symbolic entities of the resulting technologies (Sørensen 1998).

Engineering problems are often only vaguely defined and involve an important first step of analysis and clarification. Problems are not just pre-given but may need refinement or even critical analysis of the situation or the context seemingly producing the problem. This process of problem identification and definition involves non-trivial reasoning to assess the relationship between the problem and potential strategies for creating solutions – to solve the problem. This will often result in a redefinition of the problem and also a critical assessment of the availability of useful solutions (Downey 2005). This process creates a reduction from the anticipated problem(s) to the 'solvable' technical problem or as in many cases a complex construction and disciplining of artefacts and uses.

Not only the problem at stake may turn out to be vague and require a process of stabilisation but also the involved spectrum of solutions and the involved types of knowledge can vary a lot. The problem-solution relationship may as such be open ended, but the demand for solutions in engineering practice is evident, and the choice of methods and knowledge leading at least to some solution is therefore an intrinsic part of engineering. While most professionals may tend to use the knowledge they command, the spectrum of relevant solutions may be broader, and there might be a need to develop other solutions.

The heterogeneous character of engineering knowledge used in practical problem solving involves both codified knowledge based on explicit theories and models and methods and experiences based on prior work and knowledge about artefacts and situations. Codified knowledge can come directly from scientific disciplines and from standards developed in a historical process, but it can also be embedded in the knowledge of experienced engineers as a competence that unfolds as a repertoire of principles and routines transmitted through specific solutions and practical approaches (Ferguson 1992; see also Boshuisen and Schmidt 1992; Barnett 1994). This results in theories, methods, and practices representing rather different levels of idealisation, specification, and documentation.

While codified knowledge is based on reduction and specification and can be transferred in texts, models, etc. (Polanyi 1958; Kuhn 1970; Henderson 1999), the practices and routines involved in the repertoires of experienced engineers – the expert knowledge – is often less precise, dependent on the context recognition, and therefore also more difficult to transfer to others (Schön 1983; Jakobsen 1994). Engineers are supposed to handle several processes, including understanding situations and contexts, finding relevant solutions, and balancing technical and non-technical demands. This is where the routines and heuristics become crucial for the outcomes of engineering, and the competent professional seems to solve problems better (see, e.g. Patel et al. 1991; Barley and Orr 1997).

Engineering is performed in an organisational context already implying certain divisions of labour and specialisations in problem-solving activities. This also implies framing of the building of experiences and learning processes through practice. Such framed situations of problem solving and organising of engineering activities can be characterised as ‘engineering practice domains’. These domains presuppose a certain stability of the activities to make the transfer of experiences and problem-solving practices possible, though still difficult as mentioned above. An engineering domain is consequently defined as a stabilised collection of knowledge and practices organised in relation to a collection of problem-solving activities with a common base of technologies, artefacts, and routines. Domains will typically have certain common features that resemble the phenomena identified as ‘communities of practice’ (Wenger 2004), including identity and a set of standardised collection of problem-solution relations. In some cases, certain engineering science disciplines may be involved in the boundary definition of a domain, but they can only explain parts of these boundaries and the competencies involved. Also the notion of ‘mode 2 knowledge’ illustrates facets of engineering practice domains (Gibbons et al. 1994) and the continued process of change involved, especially in the case of new areas of knowledge like information technology (IT), food technology, biotechnology, and environmental management.

In contrast, the codified knowledge produced and transferred in the engineering science disciplines is based on a historical process of idealisation and reduction of the objects of study involved. While their origins often can be traced back to certain more practical problems and even distinct technological objects, the process of creating a codified science and the idealisation of the objects handled in theories and laboratories represent both the strength and weakness of these technical science disciplines. They were created in the search for more specific knowledge and solutions giving rise to theory formulation and optimisation of certain aspects of technology, but they also developed into rather autonomous knowledge communities with their own – potentially dogmatic and specialised – views of the problems to be solved, even to the point of developing their own epistemic cultures (Knorr Cetina 1999).

The role of engineering practice domains and the idealised character of technical science disciplines render engineering knowledge particular and local in its reference and dependency on specific technologies and their practical utilisation. This is countered by a continued production of standardisation procedures and a worldwide exchange of knowledge, which attempts to overcome local delimitations and to establish global technological knowledge regimes. Consequently, engineering institutions are part of a global constitution of social-ordering mechanisms installed through dominant technological solutions – a situation that results in global controversies over the choice of technologies.

A New Focus on Engineering Competence

Competence has become a significant focus in educational policy as well as industrial policy during the last 10 years. While earlier discussions concerning the design of education have been concentrated on such concepts as ‘multiple intelligence’, ‘qualifications’, ‘understanding’, or ‘abilities’, the new focus on competence is a product of wider societal developments. Competence emerges as institutions experience a widening distance between what is honoured and valued by the university and academic institutions, and the effects desired and valued by users of academic labour, producing growing interest in the ability to understand the relations between educational practices and the actual usefulness of candidates in business, politics, and industry. This reflects the outlined discrepancy between engineering practice domains and the disciplinary knowledge dominating engineering education.

One of the dynamics behind the interest in competence is the ongoing proliferation of the practical arenas of engineering. Technology is not only complex in the sense that a technological development arena comprises multiple strands of engineering specialisations. Technology also tends to be complex as reflexivity inscribed in technological development transcends professional boundaries and creates a demand for new types of knowledge, skills, and abilities. It is definitively not adequate to the modes of design education that cram the heads of engineering students with pieces of knowledge in the hope that, on their own, they will be able to find the right pieces on the shelves when they need them in their professional practice (Beder 1998).

The essence of the concept of competence is to create relations between the production of knowledge, skills, and abilities on the one hand and the practical usefulness of knowledge, skills, and abilities on the other. Moving from qualifications to competence emphasises the differences between the goals for an educational practice and the goals for a professional practice. Concern for competence acknowledges the fact that knowledge manifests itself differently depending on context, situation, and perspective. It is thus the relations between the components of knowledge and the actions performed in actual situations that are crucial in evaluating competence, not the elements of knowledge or the resources for action in themselves.

The characteristic of engineering competence is the unfolding of knowledge, skills, and abilities in a concrete practical setting where it unfolds with the relevant aims, qualities, and values culturally inscribed. This gives engineering competence the following basic characteristics (Jakobsen and Munch 2005):

- Competence is relational and contextual; that is, it is a perspective on personal performance in a context also involving organisation, norms, values, instruments, aims, and intentions.
- Competence involves the process of realisation and therefore the resources creating conditions and arguing for relevance, demanding the possession of attitudes, motives, drive, intuition, and communication.
- Competence is knowledge, skills, and abilities in a form and structure used in practical problem solving. This implies that competence relates to an authentic practice (distinguished from a designed practice).

In an educational practice, this implies that competence elements must not be separated but rather placed in a context. Knowledge and methods cannot be developed independently of the object and context to which they are connected. To have a meaningful learning process, the competence elements must be placed in relationship to each other and to the concrete question, selected universes within the discipline, professional routines, etc.

Machination and the Idealised ‘Blinded’ Eye

The critical relations between engineering practice domains and techno-scientific disciplines can be illustrated with four examples taken from different areas of engineering: (1) wind turbine development and the role of aerodynamics, (2) the identification of environmental objects of regulation, (3) formalised design methods and the role of design creativity, and (4) knowledge management and the assumptions of knowledge in practical use.

1. When the recent phase of wind turbine development started in 1970s following controversies about nuclear power and the use of fossil fuels, many researchers and policy planners – including experienced engineers and industrialists – shared the view that wind turbine design and production was a ‘low tech’ and

well-understood technology. In this context, the role of aerodynamics was considered to provide the science base for designing the rotor blades for the turbine building. This view drew on the quite substantial engineering activities carried out in the aeroplane industry and its research facilities on the aerodynamic problems and behavioural phenomena related to the design of wings, propellers, and the body parts of the planes. Though there were limitations to the understanding of turbulence and non-smooth flows, these problems were seen as related to extraordinary weather and operational conditions – eventually relevant in the design of supercritical aeroplanes – but not problems that would disturb the design of wind turbine blades and towers. The knowledge gained from experiments and measurements of wing profiles in wind tunnels (Vincenti 1990) was seen as a historic pathway to the now science-based understanding of the design principles. But this assumption proved to be wrong, as experts from Boeing and NASA later concluded. Some of the most advanced wind turbines designed on the basis of these principles broke down after short periods of operation and did not turn out to be very energy efficient (Jørgensen and Karnøe 1995). The aerodynamic problems and the loads on the structures in wind turbines were much more critical than expected. In the decades following the first experiments, a more complete picture of the specific phenomena involved in the aerodynamic operation of wind turbine wings could be established. In a sense, the differences in operational conditions between airplanes and wind turbines were simple and striking but not enough to raise questions about the generality of aerodynamics among the research-based engineers. The practical design of wind turbines, for example in Denmark, was based on test runs and small steps upgrading from one design to the next. The design work followed a distinctive pathway that took into consideration the operational conditions of wind turbines, including attention to extreme stress conditions from vibrations and unstable wind pressures along the wings and between them.

2. The key to the second example lies in the issue of environmental science and engineering taking the environment for granted as those aspects of nature that are relevant to human living conditions. Identifying environmental objects of regulation turns out to be a much more undetermined and politically influenced process in which identifying the sources of recognised pollution phenomena or health problems becomes quite complex and difficult. This complexity becomes evident not only in the problem of identifying relationships between cause and effect but also in the interpretation of multi-cause relations and synergies. It took years before asbestos was accepted as a serious health threat, just as it took years to get acceptance that volatile organic solvents can result in brain damage among exposed workers. The latter case indeed even gained the label 'Nordic syndrome' from researchers who denied the 'evidence' presented. When including environmental concerns in the design of products, uncertainties have to be included according to the precautionary principle. In these cases, the simplistic idea of evidence-based environmental strategies turns out not to be very helpful.
3. Conferences for engineering design – often dominated by mechanical and automotive engineering – assign much attention to formalised design methods.

These methods typically build on the assumption of a linear process or at least a process in which objectives and design specifications can be defined from the outset and the design activity becomes a sequence of optimisations and choices to meet these criteria. The design problems may refer to demands from customers or users, but the assumption is that these can be translated into objectives and criteria setting the stage. Even though several surveys have demonstrated that these formalised methods and models are rarely used in industrial design practice and that actual design practices do not satisfy the assumption of linearity, engineering textbooks on design continue to present the idealised methods as if their implementation is just about to happen. Especially in cases in which several engineering disciplines are involved in the development of a new artefact with functional and user characteristics only partly understood at the start of the design project, a quite different process can be observed in which involved engineers negotiate the assignment of qualities to the artefact and its technical components – in practice constructing not only the product but also the object world that makes it useful and assigns meaning to it (Bucciarelli 1996).

4. Knowledge management has already been a shared concern among engineers and business managers for a long time, under the assumption that knowledge in practical use can be handled as packages of given and codified contents – the only problem being to convince the experts that they should support this codification and packaging process. In the business world, the contemporary and growing awareness of the importance of knowledge resources and knowledge capabilities of employees to a firm's competitiveness has given this field of management even greater emphasis. Following the definition of engineering practice domains with its experience-based heuristics and routine-based activities along with the definition of competence, the picture of knowledge as something to be stored 'in machines' instead of people and to be retrieved and combined whenever new uses appear does not work. Instead, knowledge management, despite producing awareness of the fundamental role of knowledge and cooperation, ends up supporting images of IT-based knowledge handling, which might itself produce costly procedures and conservatism in the design strategies companies actually use.

In each of these cases, some limitation to the engineering sciences involved and their claimed close relationship to approaches from the natural sciences are demonstrated by the need for including other types of knowledge coming from engineering practices as well as from the realms of social sciences.

Conflicting 'Ways Out' and New Modes of Learning

The growth of the use of technology in the latter half of the twentieth century, in combination with the large investments made in engineering research by industry as well as research institutes and universities, has resulted in tremendous growth in bodies of technological knowledge, the number of new technological domains, and specialised technical science disciplines (Wengenroth 2004). Differentiation in engineering specialties puts pressure on engineering education to cope with the diversity and to keep up with the frontline of knowledge in diverse fields.

Areas that address technology and have close affiliations with engineering represent a broad variety of subjects and approaches, including, for example, pharmaceuticals, architecture, computer science, information technology, environmental studies, biotechnology, nanotechnology, and technology management. These professional areas do not necessarily see themselves as part of engineering. In some areas, new perspectives on techno-science can create novel relationships between science and technology. Such fields as biotechnology and nanotechnology have blurred the boundaries with the natural sciences as well, leading to the creation of such fields as mathematical engineering and nanotechnology in the natural sciences.

These developments have also resulted in a growing number of new specialisations in engineering, producing tensions between generalised engineering knowledge and the specialised knowledge needed in individual domains of technology and engineering practice. Examples of these specialisations include highway engineering, shipbuilding, sanitary engineering, mining engineering, power generation and distribution engineering, offshore engineering, aeronautics, microcircuit engineering, environmental engineering, bioengineering, multimedia engineering, and wind turbine engineering. This development has been called ‘expansive disintegration’ (Williams 2003), reflecting the combined expansion of the number of technologies, specialties, and disciplines on the one hand, and the continued disintegration of what once may have been the unity and identity of engineering on the other.

All these specialisations led to an increase in the numbers and variety of courses focusing on technical sciences. At some technical universities (e.g. MIT and DTU), the curriculum has been organised into modules, giving students choices about how to structure their own education. While some universities expanded the number of specialisations, others coped with disciplinary congestion through renegotiation of core contents and opted for elective courses in only a limited part of the curriculum.

Some argue for general pedagogical reform based on project-oriented work to give students a broad understanding of engineering work and problem solving, with less emphasis on the theoretical knowledge represented in existing courses and disciplines (Kjersdam and Enemark 2002). In a less radical manner, many engineering schools have tried to add certain new personal skills to their requirements and curriculum, complementing teaching in the natural and technical sciences with training in communication skills, group work, and project management. These requirements are found in the ABET 2000 demands, for example, and are included in most engineering reforms, but they do not necessarily address the problems raised earlier concerning the heterogeneous character of engineering knowledge in practice.

The dominant role of technology also demands multidisciplinary approaches and challenges the science-based, rational models and problem-solving approaches. For example, in the field of environmental studies, the need for new approaches in industry based on cleaner technologies and product-chain management challenged established disciplines in sanitary engineering based on end-of-pipe technologies and chemical analysis. From treating nature as a recipient of wastes, engineers had to accept that nature itself has been dramatically affected and that environmental knowledge had to include the design of production processes and chemicals as part of what had become a continued redesign of nature. Blurring boundaries between technology and nature has introduced serious ethical and political issues into the core of engineering.

Another example can be found in the field of housing and building construction engineering. The need for integrating both social and aesthetic elements, as well as user interaction in both the project and use phases of construction, led to several attempts to overcome the traditional division between civil engineering and architecture. Educators have tried to solve this problem by combining staff from different disciplines – engineers, architects, and sociologists – hoping that solutions would emerge from the multidisciplinary melting pot. In several cases, the integration turned out to be difficult to achieve; housing construction and city planning in engineering crumbled in spite of these attempts.

Concerns about the role of technology in society have raised issues of a more fundamental nature concerning the content of engineering education and its relation to technology, exemplified with controversies about highway planning, chemicals in agriculture, nuclear power plants, and the social impacts of automation. The concerns also questioned the role of knowledge in engineering, and critics demanded a humanistic input into the curriculum with such subjects as ethics, history, philosophy, and disciplines from the social sciences (Beder 1998). This idea was based on the assumption that engineering students, through confrontation with alternate positions and opportunities to discuss social and ethical issues, would be better prepared to meet the challenges of technology. However, in many engineering education programmes, these new subjects have ended up being add-on disciplines not integrated with engineering and science subjects, contributing further to the disciplinary congestion in engineering.

The rather mixed set of response strategies applied to date demonstrates the complexity of the challenges and the different opinions among engineering schools about how to respond. None of the single solutions seem to solve the challenges alone. Neither giving science more space by reducing engineering practice nor focusing on pedagogical methods or protecting engineering science by adding social science components addresses the full complexity of the challenges.

New Approaches to Design and Disciplinary Boundaries

Changes in the role of technologies in a society where consumer uses, complex production, and infrastructures are increasingly more important have led to more focus on the integration of usability and design features. Traditional jobs in processing and production have not vanished, but new jobs in consulting, design, and marketing have been created. These new jobs demand new personal and professional competencies, and require new disciplines that contribute to the knowledge base (Sørensen 1998).

During the 1990s, several engineering schools started new lines of education emphasising engineering design skills and introducing aspects of social sciences into engineering design curricula. These additions included technology studies, user ethnographies, and market analysis. The development of new and diverse technologies also reflects the limitations of technical sciences in being able to cover all aspects of engineering (Bucciarelli 1996; Bijker 1995). Examples of these reformed engineering programmes can be found at Delft University in the Netherlands, Rensselaer Polytechnic Institute in the USA, the Technical University of Denmark, the Norwegian University of Science and Technology, and several other places.

These transformations will – if taken seriously – fundamentally challenge the role of engineering schools in the future by including much more heterogeneous engineering programmes and new perspectives on the basic divide in the sciences between the social and the material.

Another – for the time being seemingly more dominant – solution is to accept that the idea of a single unifying engineering identity has proven to be problematic and increasingly outdated. Engineering education will unavoidably become more diverse in the future. Integrating engineering into the general university structure as suggested by Williams (2003) could be a tempting solution, removing the rigid focus on core curricula while still fighting the battle for the acceptance of engineering science. However, the problems of including professional, practical knowledge and maintaining the need for professional skills in engineering are not solved by referring students to an even more diverse science base at universities. Neither does emphasising the many new science-based specialisations in engineering provide a solution, for these may pull engineering further away from the practical knowledge also needed. Their curricula are supposed to contribute to a coherent set of engineering competencies, although they have little resemblance to established domains of engineering practical problem solving and solutions.

Although engineers' identities as creators and designers are supported in both historical writing and strategic reports about the role of engineering in the future, the reality of engineering practice seems to place engineers in roles closer to analysts and scientists in laboratories and modern technical industries. Even in future-oriented reports on engineering, there is a tendency to expect problem-solving abilities in societal and environmental issues from engineering without questioning the dominant foundations of engineering curricula (NAE 2004).

New insights emerging from innovation theory, demonstrating a broader scope of innovation practices, coupled with changes in the societal use of technology that imply growing complexity and a need for social skills, point to the need for improvement in engineering education. At the same time, innovations over the past decade are leading to changes in the role of technology that may make the role of traditional engineering competencies less central in the future. Policy and management attempts to govern innovation processes have also broadened the scope and shifted the focus from technological development and breakthroughs to a broader focus on market demands, strategic issues, and the use of technologies.

The underlying assumption in most of the training given by engineering schools on engineering problem solving is that engineers are working with well-defined technical problems and methods from an existing number of engineering disciplines. This assumption does not answer the question as to whether engineers are competent in handling the social implication of complex technologies as well as the non-standardised social and technical processes in which problems are poorly defined and involve new ways of combining knowledge. Simply broadening the science base in a more interdisciplinary direction, including especially the social sciences and humanities, may not have been a satisfactory solution due to biases in these disciplines on focussing on genuine social phenomena, leaving technology and design issues as secondary objects of study.

The mere addition of topics to the curriculum does not change engineering practices or provide a better integration of knowledge. A new engineering identity will be based on the answers to these questions:

- What competencies are necessary to manage the creative, socio-technical, and design skills that need to be improved in engineering education?
- What is the meaning of engineering problem identification and problem solving today, and how can they be reflected in engineering education?

Many reforms in engineering education, including some in Denmark dating from the mid-1970s, emphasised the need for problem solving and project work that emulated real engineering practice, but these reforms did not provide the complete answer. The response lies in a new understanding of the role of science in innovation and the use of technology in context. This approach underlines the need to bridge the divide between the disciplinary knowledge of the technical and social sciences and the practical domains of engineering with their unique knowledge and routines that integrate the social, practical and technical aspects of technology at work. It is necessary to rethink disciplinary knowledge as presented in engineering education as well as to reform the content and structure of that knowledge.

In this respect, the limitations to the engineering sciences and their models become a crucial issue as does the understanding of technologies as hybrid constructs building on several both disciplinary and practice-based knowledge components. Engineering domain knowledge of technology includes often implicit assumptions about the specific use and the context of social relations and settings that is needed to make the technology functional. In contrast, communications of the technology's specifications mostly are presented in standardised and decontextualised ways. The implicit social constituencies first show when the technology is moved into new contexts that contrast the ones in which the engineering domain knowledge was constructed.

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Chapter 14
The Local Engineer: Normative Holism in Engineering Formation

Gary Lee Downey

Abstract Engineering leaders have long tended to equate the technical contents of engineering practices with material advancements across the planet for human benefit. I call this normative holism. Taking normative holism for granted grounds images of engineering practice as knowledge in service. It also frees engineers from assigning themselves responsibility for the actual consequences of their work. Drawing on short vignettes from the territories of France, Germany, and Japan during the late nineteenth century, the approach taken here – the ethnography of dominant images – shows normative holism to be a localized phenomenon. While claiming to produce engineers to work for humanity as a whole, for example, through development, the makers of engineers have actually been following localized pathways that respond to distinct dominant images of material progress. Normative holism is a foundational normativity in engineering formation for two reasons. One is that engineering formation emerges whenever countries first form. The other is that engineers' ready embrace of normative holism makes it a key site for effectively translating critical analysis into critical participation. If students and working engineers can begin to see and analyze dominant normativities as such, might they be more able and willing to explore additional and alternative normativities?

Keywords Engineering formation • Engineering training • Engineering education • Normative holism • Material normativities • Progress • Countries

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Introduction

Engineers across the planet display a kind of certainty that fascinates me. It is the certainty of progress.

Engineering leaders have long portrayed the formation of engineers as contributing directly to human progress. They have tended to see an equivalence between the technical contents of engineering practices and material advancements throughout the world for human benefit. Official reports and vision statements for engineering formation regularly invoke such connections as "benefit to humankind" (National Academy of Engineering 2004, p. 1), "human development" (International Federation of Engineering Education Societies 2010), "development of society" (Japan Accreditation Board for Engineering Education 2010), "economic and social development" (Engineering for the Americas 2010), "match the social, economic, social, technological needs of the today society" (European Society for Engineering Education 2005), "service of mankind and the advancement of general welfare" (Indian Society for Technical Education 2010), "collective well-being (*bien-être collectif*)" (Comité d'études sur les formations d'ingénieurs 2010), and "complex and interdependent global challenges" (Anderl et al. 2006, p. 1).

Apart from the focus on humans as beneficiaries, what I find so remarkable about these normative stances is their holism. Engineers contribute to human progress as a whole. Seeking optimal gain (Alder 1997, p. 60) both as individuals and as a collectivity, they encounter and engage flows of experience as endless sources of technical problems to solve.[1] They tend to judge distinct fields such as civil, mechanical, electrical, and chemical engineering as functional technical differences that complement one another (cf. Gilbert 2009). In quantitative material practices ranging from design to manufacturing to sales, engineers see in their work optimal material gains that help everyone (everyone, i.e., in principle).

This chapter offers a brief critical analysis of normative holism in engineering formation.[2] It begins by showing how taking normative holism for granted grounds images of engineering practice as knowledge in service while freeing engineers from assigning themselves responsibility for the diverse material consequences of actual engineering work. Many engineering studies researchers have critically assessed normative holism in engineering formation and practice. The approach taken here – the ethnography of dominant images – adds to such work by focusing on how normative holism actually operates in the making of engineers. The analytical objective is to find a productive pathway for iterating moments of critique with moments of "critical participation."

In this case, the ethnography of dominant images shows, minimally, that normative holism is a localized phenomenon among engineers that has varied greatly over

[1] This is an example of what Michel Callon (1998) has called the "performativity" of knowledge enacted by its practitioners.

[2] Parts of this analysis draw from the draft manuscript *The Country in the Engineer: Engineering Formation and the Metrics of Progress* (under review).

territory and time. Responding to its diverse contents has produced multiplicity rather than singularity.

The key implication for critical participation is that this finding can perhaps better help persuade engineering educators that dominant practices of technical pedagogy also teach social values. Such could be a key step in bringing discussion and pedagogy about the implications of engineering work for broader social projects into engineering as an integral component.

Critiques of Normative Holism

Normative holism in engineering formation maps a kind of knowledge in service. It portrays engineering work as contributing to something larger than engineers. In embracing humanity as a whole, engineers typically assign themselves humble status. They serve. They serve powerfully, for identity building in learning engineering includes accepting iterations of submission and control and building a portfolio of control practices (Downey 1998, pp. 134–158). Yet the image of control should not be misread. Engineers still categorize control practices as elements of holistic service. This is one reason why engineers do not easily accept arguments that their learning and practices are gendered or racialized.

Engineers' images of service to humanity are laudable, worthy of study and, frequently, emulation. Yet normative holism also carries a key limitation: It tends to produce tunnel vision on both sides of the equivalence between engineering work and material advancement. It tends to hide the very commitments to service that official vision statements claim to be definitive.

On the side of advancement, drawing an equivalence between engineering work and human progress in general means that educators and trainers of engineers need not assign themselves responsibility for teaching students how to sort out and assess the diverse effects for different populations of any particular engineering work. Such analyses fall outside the boundaries of engineering practice. Raising questions of power and politics appears unrelated to technical engineering judgment and threatens incongruence with the image of service to a homogeneous whole. Thus, the study and mitigation, for example, of how specific engineering practices might contribute to introducing, maintaining, or exacerbating inequalities among humans is not part of engineering. The normative holism of engineers warrants a narrow focus on measurable technical performance, especially mathematical problem solving and design practices, as well as tunnel-like emphasis on the potential benefits these might bring, benefits that engineers regularly and comfortably characterize as "development."

On the side of engineers, the image of service to human progress as a whole inhibits engineers from paying attention to and examining a myriad of differences that distinguish them from one another. In particular, they typically have no analysis of how or why what it has meant to be an engineer and what budding engineers have come to value as their knowledge have varied so greatly across territory and time.

Academic researchers with Euro-American approaches to material normativities in engineering have long examined and critiqued normative holism in engineering formation and practice, both directly and indirectly.[3] Most work has called attention to its limitations by demonstrating inconsistencies with actual features of engineering formation and practice. When one diligently pursues the twin core questions of engineering studies – What is engineering for and what are engineers for? (Downey 2009) – a commitment to normative holism can appear at best delusional, at worst conspiratorial.

One set of challenges has been to the implicit claim that holistic service presupposes professional autonomy. Engineers have tended to work, after all, as employees in large organizations. Anglo-American scholars have struggled with the engineers' acceptance of private industry as an appropriate venue for their work. David Noble (1977, p. 322 and p. 324) put the issue most starkly by characterizing the normative holism of engineering service through private industry as essentially false consciousness. Engineers are a "domesticated breed," he claimed. "However firmly [they] convinced themselves that they served the interests of society as a whole, they in reality served only the dominant class in society."

On the continent, Peter Lundgreen's (1990) comparative study of engineering education in Europe and the United States had two important effects. One was to call greater attention to the paramount role played by governments in engineering and other technical education, especially on the continent. The other came from shifting attention away from job market demands in the private sector. It ignited expanded interest in the actual practices of supply through both training and formal education.

A second set of challenges has interrogated the contents of the engineering sciences and engineering design. What connections emerge between epistemic contents and normative contents? What relationships obtain between practices of formation and practices of work? Social philosophers have long mapped engineers as technological intelligentsia whose success depends upon a wide range of social, ethical, and epistemological criteria (Goldman 1984; Lenk 1984; Davis 1996). Micro-ethicists have made visible contrasts between formal codes and actual practices (Baum and Flores 1982; Martin and Schinzinger 1983). More recently, macro-ethicists make visible a range of broader material projects that engineering formation and engineering work could serve or, in some cases, do serve (Herkert 2009; Mitcham 2010).

Among design researchers, Walter Vincenti (1990) laid down a challenge by seeking to identify context-free categories of design knowledge. Yet others show that engineering designers work in different "object worlds" (Bucciarelli 1994), undertake complex practices that diversely organize people and objects at the same time (Vinck and Blanco 2003), and find ambiguity in design problems to call attention to the ethical dimensions of design judgments (van de Poel and van Gorp 2006).

[3] With the term "material normativities" in engineering, I am referring to linkages to broader socio-material projects. In what follows, I focus on Euro-American approaches because I have only begun to review other critiques of normative holism, including from East Asia.

Extensive scholarly work accounts for territorial differences in engineering formation as the product of capitalist relations of production modified by historical contingencies (Meiksins and Smith 1996, p. 253), "distinct social and institutional factors" (Kranakis 1997, p. 304), contrasting "styles" (Hård and Knie 1999, p. 42), "host cultures" (Brown 2000, p. 199), variable "codes of meaning" (Downey and Lucena 2004), and variable practices of appropriation, circulation, and transnationality (de Matos et al. 2009).

A third set of academic challenges makes visible other material normativities in engineering formation and practice. Extending Sally Hacker's early work on the masculinization of technologists (Hacker 1989; Hacker et al. 1990), some researchers have shown how the process of building practitioner identities in engineering emerged as a "thoroughly male and middle-class endeavor" (Oldenziel 1999, p. 168), tends not to recognize women as belonging (Tonso 2007), and is frequently incongruent with the dominant gender identities of women (Faulkner 2009). Others have focused on how engineering formation and practice support racial selectivity (Slaton 2010), depend upon heteronormativities (Cech and Waidzunas 2011), and actually produce multiple masculinities (Paulitz 2010). And far from advancing humanity as a whole, a robust and growing body of work documents how actual practices of engineering formation and work, especially in development contexts, can exacerbate social injustices (Baillie 2006; Catalano 2006; Riley 2008; Lucena et al. 2010; Nieusma and Riley 2010).

Seeking Congruence with Local Holisms

Despite this valuable work, normative holism continues to thrive in practices of engineering formation, including the pronouncements leading engineering educators make about it. Rather than beginning by identifying the limitations or shortcomings of normative holism in engineering, that is, what it hides, I seek to map how it operates as a dominant image of engineering practice that students should be taught.

The broader objective here is to construct sets of scholarly practices that actively iterate moments of critique with moments of critical participation. Might the work of making visible the operations of normative holism facilitate the work of nominating and scaling up practices of engineering formation that address the negative implications that fellow critics have identified?[4] This approach requires

[4] All the researchers referenced above have engaged in iterations of critique and critical participation, even if critical participation is limited to practices of teaching or public presentation. In one sense, I am just offering here one approach among many. In another sense, I am trying to persuade engineering studies researchers (and other scholars) to more explicitly articulate the connections between modes of critique and pathways of critical participation, in an effort to improve the effectiveness of critique. In Downey (2009), I argue that the question "What is engineering for?" grounds critique and critical participation in engineering studies. While the paper was in press, I realized the parallel question "What are engineers for?" does so as well.

conducting critique with a constant eye on the possibilities of critical participation. It also requires constant awareness and analysis of the limitations faced by each dyad of critical analysis and critical participation.

In this case, the first step of critical analysis is to show how normative holism in engineering formation lives as a multiplicity rather than a singularity or universal. That is, while claiming to produce engineers to work for humanity as a whole, have the makers of engineers[5] actually been following distinct localized pathways responding and contributing to distinct dominant images of material progress? To the extent such has been the case, the work of achieving normative congruence with localized and temporalized metrics of progress has influenced which knowledge practices have scaled up to dominance among engineers, producing territorial contrasts as an outcome.

Allow me to illustrate with three brief vignettes drawn from three distinct territories across a slice of time. Each vignette offers an example of achieved congruence between some dominant practices of engineering formation and a localized metric of progress.

Multiplying Specific Schools

In 1894, the *Société Internationale des Electriciens* (International Society of Electricians) finally established in Paris the *École Superieure d'Electricite*. It was clear that developing a school was not an especially high priority for the organization. The funding had been available for 13 years. A much higher priority had been establishing a laboratory in Paris "for testing and standardization" (Fox 1993, p. 205). The *Laboratoire Centrale d'Electricite* began operation 6 years before the school that would later become known worldwide as *Supélec*.

One key to understanding this delay is the fact that the private school was only providing "specific" technical education for graduates headed toward industry. The 1-year course it offered for a fee of 1,000F provided education in applied electricity for students who had already completed prior, more "general" education in engineering analysis. Graduates of the elite *École Polytechnique*, the apex of general analysis, were admitted without a further demonstration of competence. Others had to complete a difficult examination in mathematics in order to gain admission.

Over the previous century, the local makers of engineers had successfully constructed a hierarchy of technical schools to serve humanity through a hierarchy of practices enacted across a hierarchy of positions. They were helping humanity advance toward future states of increased social order, even perfection.

At the top, those students who had won promotion into the *grandes écoles* gained mastery in forms of general analysis. The sciences of general analysis, as

[5] With the term "makers of engineers," I am including engineering educators, advisers, administrators, and anyone whose work for engineers and engineering students can be construed as including pedagogical content. All contribute to the learning and material practices of engineers, hence to their making.

calculations with directionality, had emerged in the eighteenth century (Picon 1992, 2004). General analysis offered mathematical tools for diagnosing imperfections in society and nature and plotting courses of *application* in order to increase order in both (Belhoste and Chatzis 2007).[6] The activities of general analysis took off especially during the early nineteenth century when such figures as Sadi Carnot (1796–1832), thermodynamics/heat engines; Claude-Louis Navier (1785–1836), fluid mechanics; Joseph Fourier (1768–1830), heat flow; André-Marie Ampere (1775–1836), electrodynamics; Siméon Denis Poisson (1781–1840), applied mathematics; Augustin-Louis Cauchy (1789–1857), torsion/vibrations; Pierre-Simon Laplace (1749–1827), transforms for solving differential equations; Gustave Coriolis (1792–1843), moments of inertia; and Gaspard de Prony (1755–1839), hydraulics/work drew on general mathematical principles of analysis (e.g., via the calculus) to locate general mathematical principles operating in different arenas.

The mathematical practices of *application* carried the practices of general analysis outward into specific arenas, adding specific application sciences along the way. Schools further down the hierarchy increasingly emphasized the activities of specific application. They focused on what was at stake in actually intervening in some specific area of imperfections to effect increased order.

Those educated at the top were also at the center, socially and territorially. Their workplaces were both in government and in Paris. Those further down worked in provincial governments and, below those venues, private industry. Engineering service to enhance social order emanated from the accepted center to peripheries with practices that flowed from general to specific.

By 1900, the majority of graduates from this hierarchy of schools actually worked in private industry.[7] But pointing to private industry as a site for progress was risky because the mere expansion of products for sale offered no guarantee that their consumption would increase social order (Williams 1981). The earlier failure of the *École Centrale des Arts et Manufactures* to replace the *École Polytechnique* at the center by scaling up an image of progress via industrial science (*la science industrielle*) illustrated the scope of interventions required to challenge teleology as definitive of progress (Weiss 1982; Edmonson 1987).

The importance attributed to enhanced order offers a possible reason why laboratory testing was the most highly valued technical position in industry. The territorial origins of new equipment and techniques were of little consequence to such analysts. What mattered was the practice of selecting those whose implementation would have the best chances of increasing order.[8]

[6] We must be careful not to confuse the French practice of analysis called *application* with the Anglo-American image of application as the devolution of pure science into applied science.

[7] André Grelon, personal communication, September 1, 2003.

[8] Hård and Knie (1999) offer an excellent example of this with regard to the new diesel engineers. French diesel engineers did not care where engines originated. They cared only how well they worked. Another good example lies in Gabrielle Hecht's (1998) study of nuclear reactor engineering. That the French ultimately accepted a reactor design created by Westinghouse is one indicator that the teleological character of a technology in use was more important than its territorial origin.

By establishing a laboratory in Paris for testing and standardizing electrical equipment, the International Society of Electricians was staking a claim for itself as an authoritative site for defining progress in this area of specialization. This would give it status. Building a 1-year school on the low end of the educational hierarchy was necessary to produce practitioners, but its character as a specific school guaranteed its subordination.

Many new technical challenges appeared during the late nineteenth century through the vehicle of emergent industries. The *grandes écoles*, in principle, could have increased in size and shifted emphasis to make enhancing competition through private industry a primary focus. Such, however, would likely have been grossly incongruent with the long-given reality of flows of analysis from the general to the specific. For the makers of engineers to give primary attention to the messy private sector would have risked detaching themselves from service to the whole. It would have threatened to undermine their commitment to normative holism as they understood it – advancing humanity through the material pursuit of the sorts of enhanced order that could be modeled mathematically.

The particular metric of progress to be faced at that moment was to incorporate education in the new areas of *application*. The practice that scaled up was the multiplication of specific schools. By 1918, 42 new institutions devoted to training engineers for specific industrial jobs had appeared across the territory of France. Of the 42, nine specialized in electricity, 12 in applied physics and chemistry, and one in aeronautics (Fox 1993, p. 207).[9] In addition to private schools such as *Supélec*, many were new initiatives designed to invigorate the 16 regional universities established beginning in 1870. Still other schools appeared with the support of municipalities or private foundations to meet particular local needs, as was the case with the aeronautics school. All celebrated the benefits of their targeted training for specific work.[10]

Creating Separate Schools to Study and Enact *Technik*

During the 1890s, the Prussian government took the remarkable step of founding what became known as higher machine-building schools (*höhere Maschinenbau-schulen*).[11] Although only 2 years in length, the curricula of these schools included a key admissions requirement – attendance at a secondary school up to the crucial level of the 1-year military exemption, roughly age 16 or 17. This requirement distinguished the higher machine-building schools from the low-status schools for artisans, the newly established lower machine-building schools (*niedere Maschinenbauschulen*),

[9] Another 23 were founded over the subsequent two decades prior to World War II.

[10] See Chatzis (2009) for a related account of the multiplication of technical schools that explains fragmentation and continuities as "path dependence."

[11] I borrow from Gispen (1989) the English translations "higher machine-building school" and "lower machine-building school." They do a good job of naming the practices emphasized at these schools.

and the unregulated private technical schools that had become enormously popular since the 1880s in small- and medium-sized state territories, especially Thuringia and Saxony (Manegold 1978).

Establishing the higher machine-building schools did introduce an ambiguity, however, into the newly important workplaces of private industry. At issue was the work relationship between their graduates and graduates of the more elite higher technical institutes (*Technische Hochschulen)*. The latter had attended secondary school to age 18 or 19 and earned the *Abitur*, the leaving certificate that certified advanced cultivation (*Bildung*) (Gispen 1989, pp. 134–143).

After the unification of the German Empire in 1871, advocates of the higher technical institutes finally achieved success in their decades-long struggle to gain acceptance for *Technologie* as a vehicle for the emancipation of human mind/spirit (*Geist*). Advocates positioned *Technologie* as the study of *Technik*, including both technical practices and their material outcomes.

Since the liberation of Prussian territory from French occupation in 1814 and its inclusion in the German Confederation in 1815, practices of education that emphasized humanistic cultivation had gained dramatically expanded acceptance.[12] Cultivation achieved advancement for humanity through the emancipation of God-given mind/spirit (Ringer 1969). Practices of cultivation distinguished themselves in significant part by the exclusion of technical training. Beginning with Peter Beuth's success in building the Berlin Institute of Trades (1921) and a supporting hierarchy of technical schools that together served merely economic ends, advocates for *Technik* turned to schools called "polytechnical" to advance their claims for higher status (Manegold 1978; Gispen 1989; Brose 1993).

The 1870s achievement of a unified "little" Germany that excluded the Austrians provided new grounds for practitioners of *Technologie* to claim normative congruence with holistic advancement through cultivation. The number of students at technical schools grew quickly. By the late 1870s, the polytechnical schools gained the status of higher education through their re-designation as *technische Hochschulen.*

The practice of *Technologie* became a legitimate form of general education as professors developed approaches to scientific technology[13] that distinguished themselves sharply from the French emphasis on flows from general-to-specific analysis.[14] Rather than reasoning downward from ultimate physical laws to locate new laws of machines and practices of *application*, the "violent countermovement" in *Technologie* focused on reasoning upward from material experiments and investigations in search of patterns and regularities (Braun 1977).

Advocates pitched *Technologie* as an autonomous development (freed from science) that depended upon a dialectical unity of research and production. The main problem on the research side was modeling, not the application of principles. And crucially, production was primarily industrial production in the private sector, not activities vested in government (König 1993).

[12] For an early account of German humanistic education as cultivation, see Ringer (1969, p. 9).

[13] I borrow from Manegold (1978) the English term "scientific technology" as a label for these early efforts to theorize *Technik*.

[14] For analysis of the anti-French "anti-mathematicians" movement, see Purkert (1983).

Although Germany was finally unified, it was no representative democracy. Its sovereign leader still held ultimate authority to define the German collectivity and pronounce what was true and real, even in the reduced capacity as a leader (*Führer*) who was first among equals. The ascension of Kaiser Wilhelm II in 1888 marked a significant moment in the development of technical education. He helped the work of learning and practicing *Technologie* finally overcome resistance to classifying it as providing sites for cultivation. In 1900, for example, he persuaded his government to permit the higher technical institutes to offer the doctorate – the key marker of facilitating human advancement through the free exercise of mind/spirit.

Beyond the philosophical study of *Technik*, Wilhelm II also supported those seeking to redefine *Technik* itself as offering sites for the emancipation of *Geist*. During the 1890s, the image of private industry contributing to holistic human advancement scaled up significantly. Although it would never replace advancement through humanistic *Bildung*, it did gain parallel standing.

It would be the 1930s, under National Socialism, before the graduates of lower machine-building schools, artisan schools, and other vocational education programs would experience affirmation for their claims that they too emancipated *Geist* and advanced humanity by providing the leading edge of its development. In that moment, one key vehicle was creating and protecting a racially pure Aryan humanity. But as early as the 1890s, not only cultivated industrial leaders from the higher technical institutes but also shop floor managers, auxiliary engineers, detail engineers, and other middle-level personnel for the office and shop who gained their qualifications at the higher machine-building schools became authorized contributors to human progress.

They successfully pointed to increasingly specialized work in shops devoted to high-quality *Technik* (not low-cost mass production, cf. Downey 2007) as grounds for inclusion among the contributors to human progress. Their elevation became regulatory in 1908 when an organization dominated by industrial leaders designed a hierarchy of technical schools that the Ministry of Education essentially rubber-stamped.

From that period onward, engineering educators from the higher technical institutes, now the technical universities, and the higher machine-building institutes, recently promoted from *Fachhochschulen* to Universities of Applied Sciences, have produced engineers who embrace normative holism, one through the study of *Technik* and the other through its practices.

Engineering Education to Achieve Enlightenment

In 1894–1895, the process of integrating engineering education into a hierarchy of industrial schools across the territory of Japan was nearly complete. The regulations of the Minister of Education, Inoue Kowashi,[15] brought together in relation to one another the technical schools, agricultural schools, commercial schools, mercantile

[15] Following Japanese practice, I put surnames first.

marine schools, industrial continuation schools for those who did not complete middle school, and apprentice schools for workers who had previously learned trades on the job (Yaguchi 1959, p. 173).

The activities of integration followed the 1890 Imperial Rescript on Education.[16] The Rescript had continued the practice of positioning education for moral development. Importantly, it subordinated the Confucian emphasis on filial piety within the family to loyalty to the Emperor (Ueno 1996, p. 214). It defined the Emperor as a benevolent ruler (Dore 1965) who, ever since 1867 when the *Tokugawa* government, the *bakufu*, was brought down by a military revolt in the south, stood in direct relation to his subjects across the territory.

Positioning engineers at the top of a hierarchy of practices of technical education linked them to the future of the Empire of Japan and, through Japan, to humanity as a whole.[17] In concert with others, engineers would advance civilization by elevating Japan from a state of moral inferiority, ending its humiliation. Their assigned purview would be to lead developments in industry.

The image of an inferior Japan had been gaining acceptance across the collection of more than 250 clan households, or *han*, that had long competed with one another across islands just off the coast of the Korean peninsula (Morris-Suzuki 1994:27).[18] The competition had been nonmilitary in content since the *Tokugawa* household gained decisive military control in 1603. For 260 years, the *bakufu* government had kept other *han* subordinate by such measures as banning firearms, limiting contact with foreign ships, banning Christianity, and requiring leaders to spend alternative years living in *Edo*. Not a single revolt took place.

All these changed during the nineteenth century with the increased appearance of foreign ships and the expansion of imperialism by Western countries. The 1840–1842 Anglo-Chinese War (first Opium War) and resulting unequal treaty granting Britain extraterritorial rights made it clear China was no longer the most powerful outsider to Japan in the region. The image of inferiority quickly scaled up to prominence in 1853 when the American Commodore Perry appeared with warships at the entrance of Edo Bay and pointed his guns inland.

Between 1854 and 1867, first the *shogun*, the *Tokugawa* leader, and then the Emperor accepted unequal treaties with the United States, Netherlands, Russia, Great Britain, France, Portugal, Prussia, Switzerland, Belgium, Italy, and Denmark (Wada 2008). Granting these countries extraterritorial rights meant that the collection of clan households led by the *Tokugawa* household and *bakufu* government were effectively semicolonies of “blue-eyed” countries.

[16] A rescript is a document released by some authority in response to an action or request.

[17] There is no space here to detail the emergent image of advancing humanity via harmony with nature, that is, progress was not just about humans.

[18] I use the term “household” to describe the organization of the clans because the clans consisted of both people and property. The most localized household was the family household, or *ie*. Family members moved through identities *within* a family household rather than potentially gaining ownership *over* the household. A good entry point into the extensive literature on *ie* and household organization from the family to other organizations, including corporations, is Murakami (1984).

The *bakufu* responded to the new fact of moral inferiority and associated experiences of humiliation by initiating steps to grow stronger. Some of these included establishing a naval training center in Nagasaki (*Nagasaki-Kaigun-Denshujo*) as well as the Institute for the Study of Barbarian Books (*Bansho-Shirabesho*), and Warships Training Center (*Gunkan-Sorenjo*) in Edo (Uchida 1986, pp. 187–194, Numata 1989).

The *han* had been ranked according to their social distance from the *Tokugawa* household. The indicator was the relative loyalty and military performance of ancestors in sixteenth- and seventeenth-century warfare. After Perry's second arrival in 1854, several *han*, in particular the low-ranking *Choshu* and *Satsuma* households of the far south, sent young *samurai* administrators to Europe, especially the United Kingdom.[19] Their assignment was to acquire knowledge their *daimyo* (a term referring both to a clan leader and the clan as a whole) could use to protect their territories from invasion.

In 1867, armies from these two *han* defeated a *bakufu* army. With his household no longer the strongest, the *shogun* resigned. Young *samurai* leaders moved the emperor from Kyoto to Edo (Tokyo) and announced the establishment of an empire with the Emperor *Meiji* (enlightenment) as its benevolent leader. They called it a restoration.

What is crucial for us is that the image of inferiority that scaled up significantly in the 1850s attributed this status to Japan as a whole. All members of all *han* were equally inferior to the enlightened civilizations of Euro-American countries. This justified attempting to unify them as subjects of the emperor. No *bakufu* government, even one led by inventing a *Choshu-Satsuma* alliance, could likely have achieved acceptance as linking and defending the households across the territory as some sort of integrated whole (Murakami 1984).

The *Meiji* government went to work mobilizing people to end the subordination. The stories are legion and legendary. The new government used its newfound strength to break up the *han*, terminate the *daimyo*, and eliminate the *shi-no-ko-sho* categories that ranked warriors (*samurai*), farmers, artisans, and merchants. Breaking up the *han* ended stipends for *samurai* leaders.

The attribution of inferiority was crucial. It depended on the obvious absence of industry and the wealth that comes from it. What Japan needed to do to end its subordination was build industry. The government promoted the slogan "civilization and enlightenment" (*bunmei kaika*). Importantly, enlightenment here did not mean the philosophical move of distinguishing humans from nature and vesting humans with agency in relation to both nature and God. Enlightenment meant gaining industrial power (Swale 1998). Only through developing industrial power could Japan become, as another government slogan put it, a "rich country with a strong army" (*fukoku kyohei*).

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[19] They were not the first to travel to Europe. They gained special status by achieving leadership positions in the new Empire established in 1868.

The theme was military strength across a territory whose government defined all as subjects of the Emperor. Like the German empire being formed at the same time and in contrast with the European empires of the past, the new Japanese empire was like a country in that it needed to advance to survive in relation to other countries. European empires of the past had focused territorial attention on managing external boundaries, expanding through military aggression and resisting contraction through military fortifications. Like the German empire, the Japanese empire was emerging in competition with countries that were on the move. The moving country that Japan became after 1868 was an empire that framed internal development as increased strength. The main focus, the dominant image of progress, civilization, and enlightenment, was the expansion of industry.[20]

The *Meiji* government's more famous move into engineering education was establishment of the School of Engineering (*Kogakuryo*).[21] Nearly one-third of the government's budget was allocated to hire foreigners (*oyatoi gaikokujin*) to share their expertise – and then leave. To stay would be to intrude. The Scottish engineer Henry Dyer was brought in to serve as principal of *Kogakuryo*. Notably, he held control only of the curriculum, not of the school's active management, which was held by Yamao Yozo. It is also notable that students were tightly linked to work in the big mines, mills, railroads, and other projects organized by the Ministry of Industry (*kobu-sho*).[22] It is notable, finally, that the emperor visited and formally launched the school when its new buildings were complete in 1878. Only then, one could say, did the school become a recognized "household" in the empire.

By 1885, the Ministry of Industry was dissolved. The Ministry had spent huge funds on developing demonstration projects that failed to generate enough income to cover their costs. The government sold these projects off to private industrialists at great discount and shifted its efforts to supporting industry through laws, regulations, grants, and educational institutions to supply personnel.

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[20] Dominance does not mean consensus or exclusivity. Not only did many residents in rural areas live for decades without engaging, let alone accepting this image, but the sources and contents of resistance were many and variable. But the exertion of military power across the territories of the former *han* also enacted moral authority. The new regime gained the power and, hence, the authority to define – through the imputed and invoked voice of the emperor.

[21] An earlier move in response to the unequal treaties was to establish a school devoted to lighthouse construction. This school was founded by the Japanese government in 1870 and led by the British engineer Richard Brunton. It was later incorporated into the School of Engineering.

[22] It is instructive that the most literal translation for *kobu-sho* is Ministry of Industry (Wada 2008), but, following Dyer, it has often been called the Ministry of Public Works. The distinction has a difference on both sides. For Dyer, the image of public works granted elevated status in relation to industry, which was really struggling for legitimacy across Britain by the 1870 s. This image generates considerable confusion when one realizes there was also a Ministry of the Interior and the fact that *kobu-sho* was responsible for railroads and the other has responsibility for roads. For the Japanese leaders, building public works would produce progress only if the work advanced industry and the consequential accumulation of wealth and strengthening of the army. Morris-Suzuki (1994) reports it has also been translated as Ministry of Engineering or Ministry of Construction. It was clearly a ministry *for* industry.

It successfully completed a hierarchy of schools devoted to the support of industry. Formally, it drew ideas and plans from the Prussians who were building a hierarchy of trade schools. But while advocates across Prussia were expanding the population of those who could emancipate *Geist* via *Technik*, advocates across Japan wanted to expand exports and the production of military hardware.

Engineers graduating from elite universities became leaders either in government or in industry. Graduates of other schools contributed to industry at different levels according to a clear hierarchy. What is important here is that even work in the private sector served the collective good of putting moral inferiority to an end.

A Foundational Normativity

These three examples of achieved normative holism in engineering formation during the late nineteenth century illustrate their territorial and temporal specificity. The multiplication of specific schools across French territory enabled the makers of engineers to continue embracing a holistic commitment to increasing social order, sometimes in the pursuit of mathematically modeled perfection. Disrupting the linked hierarchies of general-to-specific analysis, central-to-peripheral territorial location, and administrative-to-provincial-and-private industrial employment could have been possible only if a new country was somehow emerging with a new dominant image of progress. Otherwise, efforts at disruption would simply have put the identities of graduates at risk of marginalization and alienation from connectedness to the whole. Multiplying schools was a messy, highly localized set of changes. It also produced a continuity.

Creating separate schools to focus on the study of *Technik* and its enactments in industry demonstrated that the metric of advancement through humanistic cultivation was not scaling down across Prussia. Rather, a new vehicle for the emancipation of *Geist* through a new kind of cultivation, *Technologie*, was able to scale up. Its congruence lay in providing an image for understanding the new empire as a kind of country, in contrast with the Holy Roman Empire of the past. Maintaining the unique bond between people and territory and enabling them to advance depended on images of both connectedness and movement. The higher technical institutes could not achieve congruence with the image of emancipation under the confederation, but they could when the territory became a country. The continued priority of emancipation through cultivation meant that advocates of *Technologie* could not allow it to devolve into one of the practices of *Technik*. So advocates of *Technik* focused on scaling up a separate metrics of progress through *Technik* itself.

Building a school of engineering as the apex of efforts across the Empire of Japan to produce people for industry quickly established congruence between engineering practices and the dominant image of advancement as overcoming moral inferiority. The government built a multitude of pathways for people to help the empire achieve enlightenment. The Ministry of Industry differed from the Ministry of Interior, which supervised the construction of canals, because its focus was more overtly and specifically industrial in content. Enhancing internal coherence through improved infrastructure was not the category of internal development the government sought.[23] The makers of engineers in both imperial and private universities had little trouble manifesting a commitment to normative holism. Both by leading industrial departments of the new government and serving as internal consultants in the emergent *zaibatsu* and other large private enterprises, the graduates of engineering schools could claim direct connection to the work of building a rich country with a strong army, one that had a chance of achieving parity with the great powers.

The literature exploring relationships among engineering education and training, nations, and nation-states is voluminous. Highly diverse, contingent connections to the agents of nations and nation-states have challenged the makers of engineers with mazes of localized and temporally specific normativities. In each case, they confronted teachers and administrators with choices to incorporate attention to these normativities into their educational practices or risk producing engineers with incongruent identities. Outcomes have included, for example, service in corps of engineers and colonial administrations.

These brief ethnographic vignettes suggest that, in order to fully understand the normative commitments of engineers, it is important to distinguish between the nation and the country. While the nation has emerged across the planet as naming a collectivity of people that has territorial grounding but may or may not have a territorial boundary,[24] the country has emerged differently, that is, as naming a geographical unification of people and bounded territory. Nations and nation-states rise and fall, appear and disappear. It is countries, however, that progress and regress.

Following normative holism in engineering formation brings one into contact with countries as territorial entities. Normative holisms in the making of engineers have been a territorial phenomenon of countries ever since the people and territories of France and Britain first evolved into countries and the identities "*ingénieur*" and "engineer" emerged (a century earlier across France than across Britain). Every subsequent emergent country has had to stand in relation to these two and any others that emerged in the meantime.[25]

Since countries progress, each is always in danger of falling behind others. The makers of engineers who seek to advance humanity as a whole are thus struggling with localized, temporalized metrics of progress. Through commitments to normative holism, they hitch their identities to country trajectories that scale up to dominance.

[23] In this calculus, railroads were about expanding industry, not enhancing mobility.

[24] Think, for example, of Johann Gottlieb Fichte's *Addresses to the German Nation*, which he delivered in Berlin in 1808, while it was occupied by the French. Think also of the routine contemporary use of the term "nation" to name communities of support for sports teams that have geographical loci but no boundaries.

[25] An implication of this point is that engineers across different territories are part of a single category only to the extent their makers surveyed the planet for precedents and built local practitioners through their images of engineers elsewhere (which they likely never wholly understood). Otherwise, the contrasts stand out, as emergent engineers across different territories (and even sometimes within them) gain distinct identities and significance in relation to distinct configurations of occupational identities (i.e., what it means to be a doctor, lawyer, technician, etc., also varies).

I consider normative holism a foundational normativity in engineering formation not because it is temporally or logically prior to other normativities written into the identities of engineers. Strong cases can be made that gender, racial, and heteronormativities have also always been present at moments of engineering conception.[26] These have been at least as foundational to the making of engineers across territories and time, posing similar problems of congruence and incongruence for engineering identities.

I call normative holism a foundational normativity in engineering formation for two reasons. First, it is linked to the initial formation of countries. When a country first emerges, competitions ensue among would-be makers of engineers over how to fit them to its direction of travel. Second, it is a commitment that engineers easily recognize and routinely and repeatedly embrace.[27] That makes it a key site for translating critical analysis into critical participation.

In a Fall 2010 lecture to engineers at Penn State University, I used examples such as these vignettes and even the term "normative holism" to argue that, in teaching the most mathematically intensive engineering sciences, educators are also teaching broader social values. In the United States, this tends minimally to be a commitment to low-cost production in the private sector for mass consumption (Downey 2007). In sharp contrast with reactions to my own many attempts to call attention to dimensions of gender, race, and sexual orientation, this audience reacted with recognition and openness. If students and working engineers can come to see and analyze dominant normativities as such, might they be more able and willing to explore additional and alternative normativities?

Through a transformative project redefining engineers as both problem solving and problem definition (Downey 2005), I am treating the documentation of normative holism in engineering formation as a key step to integrating more overt analysis and debate over material normativities in the making of engineers.

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[26] But not always, it should be noted, service to industrial capitalism or the design of technologies.

[27] I also maintain that other actual or potential material normativities in engineering formation must find congruence with normative holism or risk disappearing.

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Chapter 15
Eyes Wide Shut? Loyalty and Practical Morality in Engineering Education

Martine Buser and Christian Koch

Abstract The relationship between technology and society may be conceptualized as a seamless web in a form of coevolution. In modern societies, this coevolution, which includes engineering design and related ethical issues, is largely a kind of social experiment. To prevent unnecessary problems, Martin and Schinzinger suggest that engineers should seek to act ethically. This chapter examines how engineering students develop, or not, ethical concerns and practices in their everyday work. It is based on a case study using mixed methods and focusing on students in mentor companies during their Master's degree program. The educational context is understood as a Mode 2 knowledge production representing a triangular relationship between the student, the university supervisor and the mentor company where power and authority are distributed and shaped over time. Moreover, the student's role is conceptualized as being a legitimate peripheral participant in engineering practices and consequently in the enactment of practical morality. The students work on problem-oriented projects and deal with complex decision-making processes. Having to face the constraints and limits of real-life project development in an organization, they struggle within a web of technical knowledge, loyalty relationships to various actors, norms, and regulations, as well as market demands. These tensions, and their related trade-offs inherent to quick decision-making, leave little space and time to reflect on ethical questions. Nevertheless, one can trace moral concerns in the students' processes during their studies.

Keywords Student mentorships • Mode 2 knowledge • Engineering ethics • Practical morality • Curriculum

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Introduction

The work of engineers has often been described as creating and developing tools and techniques which are then used throughout the real world. In Martin and Schinzinger's (1989) book *Ethics in Engineering*, this process is presented as a form of social experiment: the work of engineers leads to innovation and technological artifacts whose applications and uses have consequences for society and the environment, but these consequences are not as equally well understood. Results can arise which have not been foreseen and which give the entire process an experiment-like feature. Consequently, engineers are asked to identify and reflect upon the moral and ethical consequences of their knowledge production to prevent "bad" use of their results. Martin and Schinzinger identified a number of necessary characteristics for engineers that enable them to act ethically in their everyday practices. However, technology development should not only be seen as taking place within laboratory walls under strict controls before being launched on the market. Authors in the fields of science and technology studies have argued that there is no unequivocal link between technology and development (e.g., Bijker et al. 1987). Besides, technology itself is the product of social and cultural forces. The relationship between technology and society may best be conceptualized as a seamless web in a form of coevolution. In modern societies, this coevolution is largely an open-ended process and thus partly unpredictable. As such, moral and ethical issues cannot only be described as the responsibility of a single individual or group of actors but are also shaped and defined in different contexts by all the actors taking part in the development, production, and uses of technology. Researchers agree on the necessity to reflect on ethics in particular contexts. Lynch and Kline (2000) emphasize that ethics should be studied as part of the socio-technical aspects of engineering taking place in real-life settings and by paying specific attention to "the complexities of engineering practices that shape decisions on a daily basis." Accordingly, we delimit the specific context in which these ethical issues are embedded and become sufficiently challenging for reflection. Here, our context is a Mode 2-based MSc in Engineering program where students work in a mentor company for two days a week. Based on a case study focusing on the students acting in their company, this chapter seeks to understand how and under what circumstances these students show ethical concerns or reflection during the two years of their master studies. Do they close their eyes or do they act? Kubrick's male character (Dr Bill Harford) in the film "Eyes Wide Shut" faces the same choice, yet he is also caught in a complex social game as our students appear to be in their companies.

The chapter draws on community of practice-based learning theory, in particular the notion of legitimate peripheral learning which describes the development of an apprentice when entering a new work community (Lave and Wenger 1991). The social experiment discussion is revisited further with respect to the mentor context in order to describe the position and development of the students.

The chapter is structured as follows: First, we describe the MSc in Engineering study program as embedded in a Mode 2 production of knowledge. Second, this is developed into an understanding of the student as a legitimate peripheral participant in two different communities, namely, the company community and the academic community, both of which have specific understandings of what engineering is. Third, we describe some characteristics of engineering ethics using the social experiment approach of Martin and Schinzinger as well as a presentation of the notion of moral practices. Fourth, we present the findings of a case study in which we focus on experiences from engineering education. The aim is to challenge the arguments developed in the theory using these practical examples. Finally, we conclude on the circumstances of raising ethical concerns and the possibility of taking a decision to act.

The Context

Our context is an engineering Master of Engineering degree program offered at Aarhus University, Herning. The setup is a tripartite arrangement combining a study program, a mentor company, and a university. The MSc in Engineering takes place in collaboration between a student, a mentor in a company, and a supervisor from the university, commonly referred to as a mentorship. Traditional university education, including engineering, can be said to be embedded in Mode 1 knowledge production. Mode 1 is a rather closed knowledge system managed by canonical norms and collegial authority (Gibbons et al. 1994). In contrast, Mode 2 knowledge production is found in open environments that are dynamically interactive with outside social interests. Such knowledge production will, according to Gibbons et al., be application-based, transdisciplinary, and heterogeneous involving socially distributed knowledge encompassing reflexivity and accountability and new types of quality control (Gibbons et al. 1994; Musson 2006). It may be argued that contemporary engineering education in general is far from matching those defining characteristics. Our more modest point is that when looking at the role of students enrolled in our MSc in Engineering degree program, the interplay in the tripartite constellation can be viewed as a Mode 2 production of knowledge (Gibbons et al. 1994; Nowotny et al. 2001).

Gibbons et al. suggest a rethinking of the university-company relationship, seeing knowledge increasingly as a coproduction between universities and companies rather than merely a university undertaking. Thus, the space for research has moved into a more nonphysical "in-between" space in their coproduction of knowledge. Nowotny et al. (2001) develop this further by discussing the "agora" as metaphor for new spaces for multiple actors in knowledge production in spatial contexts disjoined from simple boundaries between universities, enterprises, and other institutions. Interestingly, Barley and Kunda (2004) conceptualize the commercial relationships around technical contractors in a somewhat similar vein when they note that knowledge workers effectively enter a bazaar when they sell themselves.

A characteristic feature of the degree program is that, in addition to two days of traditional courses and teaching at the university, the students work in a mentor company the rest of the week, using the real work setting as basis for their practical and theoretical progression. The core of the MSc study program is innovation. The students must carry out projects that focus on issues, challenges, and opportunities of innovation for their companies. They define the framework and the objectives of their projects in cooperation with the mentor company and in compliance with the curriculum of the study program. Consequently, formulating projects relevant to company issues is primary. Here, the difference between other types of student placement, such as internships or traineeships, is apparent as these usually focus on the learning of everyday operational routines of the company.

We argue that the main similarity between our tripartite mentor organization and the Gibbons et al. (1994) and Nowotny et al. (2001) perspective is the emphasis on the need for multiple players in (attempted) purposeful knowledge coproduction activities in innovation processes and in joint projects. However, it is important to note that a research phase takes place within an educational context where the main collaborator is the student who is provided with a set of academic rules and demands which Mode 2 would usually not include. Musson also discusses this in her study of engineering education in South Africa (Musson 2006). However, as Mode 2 enables us to look at knowledge production as a problem solving process, engaging different actors with different backgrounds to be involved in the process of production, ethical questions are consequently not only dealt with by a specific group of actors, such as engineers, but are more widely distributed and discussed by all the actors taking part in the production of knowledge.

Now that we have defined the context of the social experiment, we can look at how the roles are distributed among actors.

Legitimate Peripheral Participation

In their various writings, Jean Lave and Etienne Wenger, as well as their critics, (Contu and Willmott 2003; Storberg-Walker 2008; Tennant 1997) provide a set of concepts which are useful for understanding our mentorships, since they focus on learning as a longitudinal process. To underline more specifically the role of students in the mentorships, we refer to the concept of “legitimate peripheral participation” (Lave and Wenger 1991). The notion was suggested in order to understand how apprentices learn in the workplace and as part of a community of practice. A community of practice can be defined as a group of practitioners sharing a concern for the work they carry out as well as learning how to improve this as they interact regularly (Wenger 2002). At the very core of the legitimate peripheral participation concept is an understanding of how newcomers are accepted and incorporated in a work context. Equally important is the appreciation of the intimate link between learning, knowledge and practice. It should be noted that Lave and Wenger do not propose craft apprenticeship as an institution to be reinstalled as a schooling instrument. Rather, they propose apprenticeship learning as a way to think of learning processes in educational contexts (Lave 1997).

In their initial conceptualization of legitimate peripheral learning, Lave and Wenger (1991) define apprenticeship as a process of becoming a member of a community of practice. By observing and sharing through peripheral activities, the newcomer becomes familiar with the tasks, vocabulary, cultures, habits, and organizing principles of a specific community (Lave 1997, p. 33). Through this engagement in a common structure pattern of learning experiences without being taught, examined or reduced to mechanical copiers of everyday tasks, they would become skilled and respected master craftsmen (Lave and Wenger 1991, p. 30). Lave and Wenger subsequently underlined the ambiguity, dissent, and dynamics of the learning and its context. Lave (1997) thus proposes to think of apprenticeship as "an improvised, opportunity and dilemma based learning process" (Lave 1997, p. 34) and Wenger (1998, p. 79) underlines how differences in interpretation occur and are negotiated in the construction of joint enterprise.

Both Lave and Wenger address the relationship which the peripheral learner might have to the community alone and together with other members. Wenger (1998) describes the negotiating of joint enterprise as "not just a stated goal, but creates among participants relations of mutual accountability that become an integral part of the practice" (Wenger 1998, p. 78). The peripheral learner is interwoven with an ongoing creation of negotiated preferences inbuilt in the joint enterprises and also, through the mutual accountability in the community, is expected to be loyal to its other members. Even if Lave and Wenger do not directly address issues of loyalty and ethics, the latter can be derived directly from their analysis of learning processes. It can be assumed that within the position of the learner and the community characteristics, loyalty and moral issues are embedded in the workplace learning.

When referring to the critics of the concept of legitimate peripheral learning, the issues related to loyalty become more complex, since the valorization of work process, the labor contract and the employment relations are seen to construe the position of the peripheral learner in their community (Contu and Willmott 2003).

The notion of a peripheral learner was extended by Star (1991) who notes that multiple marginalities might be the "curse" of the learner, being a member of multiple communities (here the company and the university) placing the learner in a high tension zone in-between accepted communities, negotiating rival allegiances: "at once heterogeneous, split apart, multiple and through living in multiple worlds without delegation we have experience of a self unified only through action, work and the patchwork of collective biography" (Star 1991, p. 26).

Here, however, the students are supposed to contribute to innovation in the company; thus, entering an even more liminal zone (Czarniawska and Mazza 2003) as the stability of existing work practices is to be broken down. The community of practice approach and the notion of legitimate peripheral participation therefore bring insights as well as having several limitations. First, the engineering students are not involved in a stable engineering culture or community of practice (Kunda 1992; Koch 2004). Rather, they operate on the edge of several communities. Second, the concepts of community of practice and legitimate peripheral participations have been rightly criticized for delivering a too rosy and peaceful image of enterprise collaboration and under-illuminating issues of power and control (Tennant 1997;

Contu and Willmott 2003). Tennant claims that situated learning theory, in its proponent's eagerness to depart from formal education, forgets the power issues linked to the learning situation regarding knowledge ownership and control. Contu and Willmott (2003) point out that years of research in politicizing processes of practice risk being lost in Wenger and his followers' harmonious notions, such as "joint enterprise," mutual engagement and shared repertoire (Wenger 1998). In this educational context, power and control, institution and conflict are ubiquitous.

Engineering Ethics

Martin and Schinzinger (1989, p. 26) define engineering ethics as the study of moral issues and decisions confronting not only individuals involved in engineering but also the various organizations dealing with their related practices. But their definition includes many more actors in society such as consumers, managers, scientists, lawyers and government officials who are also confronted with questions about moral conduct, character, policies, and relationships of people and corporations involved in technological activity. Further, they conceptualize social experiment as

> the framework for discussing various aspects of responsible engineering practice: imaginative foreseeing of possible side effects, careful monitoring of projects and respecting the rights of clients and the public to make informed decisions about the products which affect them.
>
> (Martin and Schinzinger 1989, p. 18)

However, Martin and Schinzinger (1989) acknowledge a number of pitfalls which are challenging and therefore condition the work performed by engineers. They recognize that there are many challenges to acting as responsible actors in their daily work:

> They include: the pressure caused by time schedules and organizational rules restricting free speech; the narrow division of labor which tends to cause moral tunnel vision; a preoccupation with legalities; and the human tendency to divorce oneself from one's actions by placing all responsibility on an authority such as one employer.
>
> (Martin and Schinzinger 1989, p. 103)

Therefore, the possibility to reflect on and identify ethical questions is not straightforward when engineers deal with everyday practices. Either they do not recognize the moral challenges embedded in their decisions or they see their own role as neutral and pass the task on to managers or politicians to engage with the moral debate and make decisions (Van de Poel 2001; Munch 2005). We call the latter mechanism "referral." Van de Poel and Van Gorp (2006) have pointed out that designing engineers when facing many external constraints deal with few ethical issues, arguing that especially in the case of "low-level normal design," relevant decisions are already embedded in technical norms and codes.

Kunda's (1992) analysis of engineering cultures underlines the multiple tensions and dynamics that can be found in engineering work, also when involving external collaborators (Barley and Kunda 2004). Munch's (2005) study of the practical morality of engineers is carried out in a similar engineering context. She shows that moral and ethical issues are occurring as part and parcel of the production of knowledge. Engineers mitigate their expert responsibilities and the ethical issues derive directly from these processes of knowledge production. New knowledge and learning thus lead to new ethical and moral issues.

The engineer's practical morality draws on a pragmatic ethic of benefit where "the good" and the "decent" lie with the impact of actions, typically whether projects are a success and the client is satisfied (Munch 2005, p. 106). Munch finds that the complexity and dynamics in the organization of engineering work and tasks push toward an ethics of benefit leading to the disregard of ethics of virtue or duty. She argues that if ethics of benefit is not made explicit and managed somehow in a collective process, there is a risk that the push for ethics of benefit leads to an emotional and subjective ethics and a further individualization of the responsibility of decisions (Munch 2005, p. 138).

In order to help the engineers to be able to act ethically, Martin and Schinzinger (1989) identify a number of necessary individual characteristics. They refer to the concept of responsible agency which involves the following features:

1. Conscientious commitment to live by moral values
2. Disposition to maintain a comprehensive perspective on the context and possible consequences of one's actions
3. Autonomous, personal involvement in one's activities
4. An acceptance of accountability for the results of one's conduct.

(Martin and Schinzinger 1989, p. 103)

As Van de Poel and Verbeek (2006) suggest, in order to be meaningful, ethical questions should only be treated within the specific context in which they appear and be studied in relation to this context. The following case study focuses on how ethical questions are identified and dealt with in various situations where students confront their academic knowledge with the practical reality of enterprises. The purpose is to describe the context in which the dilemmas occur in daily life and how they are managed by the engineering students.

Methods

The empirical material is drawn from ongoing research on the mentor carried out at Aarhus University, Herning, within the MSc in Engineering study program over the last 3 years (Buser et al. 2011; Buser and Jensen 2010). In the present chapter, the study is presented as a case study which focuses on students' ethical development. It uses a mixed methods approach combining qualitative and quantitative studies. The qualitative research encompasses the two authors' participant observation for the last 3 years. This includes teaching, negotiating contracts with the mentor companies, supervising more than 40 students for a minimum of two semesters, and examining their projects in the presence of external examiners. In addition, 17 qualitative interviews with students, company mentors, and supervisors were carried out during the winter 2010–2011. This was complemented by a quantitative survey made in the spring of 2011 with engineering students active in the second and fourth semesters. The response rate was 68% for a population of 60 students (Buser et al. 2011). The fact that the authors of this chapter are part of the academic team active on the MSc program provides an in-depth insight into what takes place during the mentor program. However, the authors must be careful to keep the necessary critical distance in terms of their involvement and commitment. The trustworthiness of the results is achieved through triangulation by the comparison of information collected through different channels (Bryman and Bell 2011).

Students in Enterprises

The following discussion builds on Martin and Schinzinger's four features: the first is to be aware of moral values and be able to recognize ethical dilemmas; the second consists of being able to have a comprehensive perspective on what happens in a given situation and the consequences of actual decisions; the third focuses on the possibility of acting autonomously within the process, being able to verbalize doubts or disagreements; and the fourth aims at being able to act according to moral choices and take responsibility for one's conduct.

But before presenting the case study, it is important to stress that in the questionnaire noted above, only seven out of 41 respondents (17%) spontaneously acknowledged that they face ethical or moral dilemmas in their mentor company and this only "to a minor degree." The interviews, supervision, teaching and observation, however, show another picture, though the issues we present here may not be recognized as moral or ethical by the students.

Being Aware of Moral Values and Dilemmas

Moral concerns appear even before students begin their study. First of all, this is seen in their choice of company, since many students are attracted by sustainable production or solutions, giving their preferences to companies with a green profile or being active in alternative energy, such as wave energy or wind turbines.

Then, secondly, as students are required to find their mentor company themselves, the negotiation process to be accepted as mentee can be difficult to balance: on one side, the desire to look competent and professional and, on the other, the difficulty to assess one's own skills:

> I hope I'm good enough and can be helpful to my company and deliver what they expect me to. I wouldn't like them to be disappointed and feel I had misled them in terms of what I can.
>
> (M. male student, 24 years old)

Once the study has begun, the first weeks are marked particularly by uncertainty, since the students must manage two new working communities, that is, the enterprise and the university. This may lead to an identity problem:

> I don't know what to do when I visit a competing company. Do I present myself as a student and get as much information as possible, or should I announce myself as employee of the mentor company knowing that it will limit my access to interesting information?
>
> (K. male student, 24 years old)

This conflict of interest is shared by many students who discuss it every first semester during a study course on the MSc program. The course also addresses more general ethical issues related to scientific research and ethical behavior within a company, and these are discussed by students who easily express their opinions. However, they clearly state that they do not feel they have a role to play in the decision phase in real life:

> Who am I to decide what should be done in a situation of controversy? I'm just a student and there are so many issues I don't understand or even don't have enough knowledge of in these discussions. I don't have the competences and it is too complex.
>
> (B. female student, 24 years old)

Within the company, students may feel insecure about expressing their own views when facing experienced practitioners. This integration phase can be time-consuming; our questionnaire shows that an average of 2–4 weeks is needed to understand the company specifics, but it takes up to 4 months for one third of the students to feel comfortable in their new environment. Companies, especially those that mentor more than one student, recognize that this adaptation phase is necessary. During these first months, the students very often start identifying themselves strongly with the company of which they are part: "We, at XX, do this and that…. We are the leader on the market…. We have a social concern…. We are interested in reducing pollution." Most students begin by repeating the company and mentor position without reflecting on its actual content. But for some, the gap between company rhetoric and its actions reveals inconsistency or disparity and, as a result, students start questioning their context; for example, does the company in fact aim at reducing carbon dioxide emissions or is it just a marketing argument (M. male student, 25 years old)? This leads us to the second feature.

Comprehensive Understanding of the Contextual Situation

A phrase every supervisor hears after a few weeks from each student in a mentor company is

> I can't define my problem statement now. I need more time to find out what they (the company) are doing. There are so many things I don't understand yet.
>
> (B. female student 24 years old)

This quote shows insecurity, but it also reveals the will of the students to be able to really understand their surroundings. It is not uncommon that a student who becomes more knowledgeable over time rephrases the problem statement or even identifies other relevant aspects of the organization before working on the former process under focus. A revealing sign is that the student realizes that companies do not always share a unified position: conflicts and disagreements indeed coexist within the same space. Taking sides most often signifies accepting the mentor view of the problem (which most students appear to do), but some students have succeeded in giving voice to competing positions and thus expressing moral concerns.

This tension between what the companies/the mentors expect and what students find out may be managed in different ways, but it usually constitutes a crisis for the students who find themselves torn between mentor expectations and their own understanding.

An example can be found in the various collaborations between Denmark and China where several large companies have been involved. The companies are caught between the necessity to develop collaboration with Chinese engineers and the fear of being betrayed by them. For example, a company has started an innovation process between the two countries, but the Danish part delivers 10-year-old documentation and specifications to their Chinese collaborators to avoid being circumvented. This kind of decision prevents projects being fully developed. Students often express their disillusion in a university context but can choose to accept company decisions:

> I'm supposed to deliver a knowledge management tool for this collaboration, but I know it won't work as the problems are somewhere else. I would rather work on another subject, but my mentors want me to work on this one.
>
> (P. male student, 24 years old)

And then, they may end up reproducing the mentor point of view without taking into account their own reflection:

> The Chinese culture as based on Confucianism is not aiming at the innovation process, since employees don't dare to contradict their superiors.
>
> (Conclusion of a student project, X. Chinese male student, 25 years old)

This can lead to difficulty regarding their academic assessment as obviously the conclusion of the project does not address the issues described.

Another example of the importance of contextual understanding is when students realize that the mission they have been given may have drastic consequences on the company:

> What if they fire people after my analysis? I don't want that to happen. I don't want to be the boss' spy. I would feel awful.
>
> (L. female student, 36 years old)

Nevertheless, during the second semester, the majority of the students are able to distance themselves from their mentor and express their own understanding. This is described in the next paragraph.

Autonomous Involvement

If the student is able to identify contradictions or misalignments within their surroundings, the student is in a critical moral position: either to act or to ignore and accept if they are to engage in challenging the community they have just entered:

> I think my mentor is part of the problem. The way he manages, or rather doesn't manage, creates big problems for all the employees, but I can't write this, can I?
>
> (M. female student, 24 years old)

In expressing doubts and engaging in a discussion with the mentor, the student underlines a disagreement and therefore risks damaging their relationship with the community. For many, the mentor company represents possible employment at the end of their studies. It is easier for the student to follow their own considerations if there is not a job at stake:

> I have chosen not to work on the problem given by my mentor. I thought it was a fake and instead, I work on the company organization and dysfunctions. I learn more by doing so, but no one is going to read it in my company. It will end up in a drawer, but I don't care. I have found a new company for my MSc.
>
> (M. female student, 25 years old)

But experience shows that the students who confront their mentor not only gain self-confidence but also receive recognition from their mentors. Competing understandings can in turn be developed to a new common view and, thus, integrate the student even more in the community. In situations of doubt or crisis, the academic supervisor can also play a role, either as a source of objective reflection, as a negotiator, or as a support to the student.

Acceptance of Accountability

Acceptance of accountability is the consequence of the moral choices made by students when facing ethical problems. Here, this decision is often reduced to simply accepting or not accepting being part of the given project:

> I had a conflict with my mentor on the quality of what we produce and this was really unpleasant. I'm not going to repeat this. I will know better in my new company.
>
> (E. male student, 25 years old)

The "keeping silent" strategy does not always mean bending in front of the mentor, but it may lead to the student changing company and searching for a new mentor where they will feel more comfortable. But being outspoken in the company can also be beneficial not only to the students but to the company, helping it to focus on specific problems:

> For a long time, my mentor thought I was wasting my time on an irrelevant subject (manager's role in innovation transition phase), but now part of my recommendations are going to be implemented to strengthen the transition. It's cool.
>
> (A. male student, 24 years old)

In conclusion, some of the students are ready to take responsibility for what they think is wrong or bad and to assume the consequences of their choices, although we have to recognize that being able to act ethically is not a given competence here, but rather is achieved over a (sometimes) long process.

Discussion

As confirmed by the literature (Van de Poel and Van Gorp 2006; Munch 2005), the identification of explicit ethical questions is not straightforward for students in their everyday practices. They fail to identify or recognize that the doubts and questions they encounter are ethically related. They tend to see ethical questions as connected to more general discussions and choices, for example, in technological controversies. When confronted with these more outright moral challenges, students tend to let other actors make the decision. Their mentee situation reinforces the perception that they are not supposed to take part in debating these issues. As peripheral learners, they do not see themselves as experienced enough to give a qualified answer or to be heard as a competent actor. This is confirmed by the companies' representatives who do not expect the students to interfere in the decisions they have made.

Using the concept of peripheral learner, the case showed that nevertheless there is an option during the student project to develop a personal reflection mirroring moral issues. In the beginning, initial understanding enables the student to commence collecting actors' interpretations and knowledge, and this process sheds new light on the initial understanding of the problem. Gradually, a new understanding of the problem emerges, and new players and their knowledge become relevant. However, when a student is able to develop new knowledge and reflect on ethical questions, it does not mean that these are translated into actions. The challenge is then to choose between two attitudes: either shutting one's eyes (to keep silent and accept the dominant understanding) or to express doubts and engage in a discussion with the mentor. In doing the latter, the student underlines a disagreement and therefore risks damaging the relationship with the community, since the company must be in a position to listen to the student's comments. The non-referring strategy may also lead to the student finding a new mentor company. In this situation, the student needs to feel confident enough to express or defend their position. This process signifies that the student is "solid" enough to progressively detach themselves from the personal mentor's view. To act ethically, the student will have to resourcefully and intentionally manage issues of power, authority, and loyalty, parallel to that described by Contu and Willmott (2003). Even if classical mentorship requires full loyalty of the mentee, the student can and should act as a responsible agent.

A dominant group of students choose not to refer to those issues, whereas a smaller group is able to develop and articulate an explicit position. Non-referral occurs, for example, when manufacturing companies seek new production technologies. When discussing the consequences of technology, we observed that our students delegate responsibility to the company or the users and do not feel legitimated to criticize the products or technology as such. But this does not mean that students do not have moral conflicts during their mentorship. Most of the time, the nature of these conflicts is linked to the differences of perception between the student and their mentor or colleagues.

Regarding the characteristics of ethical behavior identified by Martin and Schinzinger, we can identify a kind of progression from understanding to action, from being able to identify moral issues to taking a position, to acting accordingly, and, finally, to being responsible for the consequences of one's own actions. But this development very much takes place in interaction with the social processes in the company. The practical moral issues are numerous, but they recurrently refer to human relations and being a member of a community. The student has to decide between keeping their doubts to themselves and playing the game as defined by the mentor or to confronting the mentor with a competing understanding. They may also view their condition as individual and isolated when dealing with ethics as emotional and subjective questions leading to a further individualization of the responsibility of decisions as described by Munch (2005). The development of a practical morality cannot, however, be reduced to individual choices, but is highly integrated in the production of knowledge in the engineering community. This observation is in tension with the non-referring ethical issues that the student experiences. The "silencing as a community" phenomenon implies the shaping of docile employees. Support given by the university supervisor is often important in order to confirm in the student the coherence of their analysis. The role devoted to the university is then to help the student to carry out his/her analysis by relying on a systematic production of knowledge.

The dilemma goes hand in hand with identity problems as described above. Should the student perceive himself or herself as a student or an employee from the mentor company? This double identity forces them to reflect on their role and position. The double identity also tends to serve comfortably in non-referral coping. The student informs the supervisor about all the taboos of the enterprise and the enterprise mentor of all the taboos of the university. As a supervisor (and mentor), one might find oneself in a role as a confessional partner, yet voicing frustrations in another context indirectly leading to apparent stabilization of non-referring and consent.

Students in enterprises work with problem-oriented projects and deal with complex decision-making processes. Facing the constraints and limits of real-life project development in an organization, they need to operate within a network of organizational and technological knowledge, loyalty to various actors, norms, and regulations, quick decision-making and market demands. These tensions leave little space and time for reflection on ethical questions (Evans et al. 2004; Koch 2004). Another important area of possibly explicit ethical consideration is the formulation of the study program by the university teachers and administrators. There are many tensions between commercial and societal concerns, between management and employees, between normative model and contextualizing theory, etc. All of these could lead to ethical concerns related to the pertinence of the student's education facing the realities of the work practices they see. But we witness relatively few articulations of such ethical elements. In fact, most students tend to prefer practical tools over theory which we here interpret as indirect consent to the strong business orientation within their education.

Conclusion

Studying engineering in a Mode 2 context is closely intertwined with construction of loyalty toward the community within the enterprise which leads to negotiation of preferences and ethics. It also leads to individualization as the student's position involves boundaries between other communities with ambiguous references and the tendency of not attempting to manage an ethical issue if one arises. Students develop competence in relation to conscious commitment to live by moral values. They develop a disposition to contribute to a comprehensive perspective on the context and possible consequences of their actions, an autonomous, personal involvement in their activities and an acceptance of accountability for the results of their conduct. The development of these aspects of a practical morality cannot be reduced to individual choices, but is completely integrated in the production of knowledge in the engineering community.

In order to attain the freedom to adopt responsible agency as defined by Martin and Schinzinger, our students need to resolve loyalty issues in the communities, company and university of which they are part. This can only be achieved if the student is aware of the fact that their doubts and worries are not only confidence issues but rather a challenge inherent to their position and development as a member of the two communities. This is legitimate peripheral learning. Our role as teacher is to contribute to the gradual, partial, and ambiguous description of these processes with the students and to give our students the tools to mature and be able to act as responsible engineers: thus, to enable them to act with their eyes wide open.

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Part III
Rethinking Perspectives on Engineering, Nature, and Society

Introduction

Martin Meganck and Yanming An

While reflecting upon the essence and identity of a phenomenon, valuable insights can be gained from comparisons between similar yet supposedly different phenomena. Working this way, qualities and attitudes can be brought to light of which one was not aware before. It sometimes takes an outer view to reveal factors which are all too self-evident when regarded from within. "*Fish are not aware of the water*". Yet in so doing, it is tempting to focus almost exclusively on differences. The particular way in which questions are asked can cause a shift of attention towards one specific aspect, thereby neglecting that the questioned phenomena may have a lot in common. When asked to reflect upon "man and woman", one will probably highlight the differences between men and women, and pay less attention to many things they might have in common. The same type of argument applies to questions regarding "human and animal", or different cultures.

The major part of this part consists of chapters comparing American, European and Chinese approaches to topics or cases linked to scientific and engineering work. The only exception is Chap. 16, which has its focus on the career path of former members of the association *Engineers without Borders* in France. However, in the wider perspective, also this chapter has a comparative ambition in the sense that the focus is on the impact of early intercultural experience on later professional career paths. In Chaps. 17, 18, 19, 20, and 21, the American-European-Chinese comparison is made within each individual chapter. Chapters 22 and 23 however can be best read as a duo: Chap. 22 has its focus exclusively on aspects of Chinese culture, whereas Chap. 23 focuses on aspects of cultures from the Judeo-Christian tradition. Comparative insights may thus be gained from the juxtaposition of both. In the latter

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chapters, the highlighted aspects are mainly of a spiritual or cultural-philosophical nature. In the other chapters, there is more room for political or economic aspects.

In Chap. 17, Rodríguez, Hu Mingyan and Fisher examine whether, and if so to what extent, research policies in the United States, the European Union and China are demanding the integration of socio-ethical considerations into science and engineering research practices. In the USA and the EU, the study of socio-ethical aspects of science and technology started originally as parallel initiatives, alongside but separate from proper scientific research. Since the early 2000's, the analysis of social, ethical and legal issues has tended to become conceived of as incorporated into scientific and engineering R&D. Here, in particular, projects related to the later European Framework Programmes and nanotechnology in the USA serve as examples. According to the authors, there is also a growing interest among Chinese scholars in socio-technical integration, even if there is little or no encouragement and support in that regard from formal policies.

Three chapters deal with very specific large-scale technological projects, for which Chinese cases are compared with western ones, viz. Chaps. 18, 19, and 20. In Chap. 18, Wang Jian and Chen Jia consider *industrial heritage conservation* to be an aspect of engineering ethics. Inherited artefacts, as manifestations of human labour, are seen as mediating objects between generations. Hence, respect for past generations' artefacts is a way to show respect for past generations *tout court*. Similarly, they interpret sustainability as to insure employment for future generations. The authors continue by discussing two cases of dealing with industrial heritage – one in Germany, the other one in China. Upon the decline of the coal and steel industry in the German Ruhr District, original plans to destroy industrial installations were changed, pushed by academic interests from archaeologists, interested public constituencies and private stakeholders. In China's planned economy, there has been far less public participation in decision-making processes regarding industrial heritage preservation, resulting in complete demolition of the Shenyang industrial site, in order to make place for reconstruction.

China's *dam construction* policy has also raised a number of questions, especially abroad. Zhang Zhihui in Chap. 19 traces back historical differences between the USA and China, both concerning dam construction itself as well as themes related to engineering ethics. Criticisms and experiences in the West seem to brim over to the Chinese situation. Whereas programmes developed by Chinese authorities tended to remain unquestioned in the past, in recent years, ethical and societal studies have become possible in relation to these programmes. Zhang argues that specific situations require specific approaches, also in ethics. The historical, geographical, social and cultural situation in China differs in many ways from the contexts in which other dam construction programmes function worldwide. Therefore, considerations and ethical standards which may be relevant elsewhere cannot be directly transposed to a Chinese context. The establishment of a set of specific Chinese ethical guidelines can help mediate the opposing perspectives of pro-dam and anti-dam advocates, balancing issues such as the needs of economic growth and environmental protection, as well as the interests of all people whose lives are affected.

Railroads are another major technological achievement, often considered as both a result and a driver of industrial development. In Chap. 20, Wang Nan gives an overview of the development of railroads in the USA and China. To the historical facts and figures, she adds considerations on planning, financing, standardisation and regulation, as well as exploitation conditions. The comparison indicates that the development of railroads may be affected by multiple factors, such as economic, political, technological, managerial, institutional, military, cultural and environmental factors. At times, non-technological factors have impacted much more than technological. The development of railroads in any country in the world depends on the comprehensive function of all of these factors.

If one considers society as a complex system or machine, then the group best equipped to act as governors of the system would be engineers. That at least was the opinion of the American-Norwegian sociologist and economist Thorstein Veblen. In Chap. 21, taking Veblen's book *The Engineers and the Price System* as point of departure, Mike Murphy and Eugene Coyle re-examine the roles of engineers especially with respect to their leadership functions in Europe, the USA and China over the last two centuries, but more particularly over the last 50 years. Here again, things can be best understood by respecting the interconnectedness between political, economic and other societal factors, either by the need for engineers in industry in Western countries or for merely political reasons such as the Cultural Revolution in China. Few engineers were drawn to positions of political leadership in Europe in general and in Ireland in particular with France as an exception. This contrasts strongly with the political reforms of the past few decades in China which fostered engineers to take political responsibility, that is, leaders who were both *Red and Expert*.

The last two chapters of this part can be read as a diptych. Taking some distance from economic or political considerations, Wang Guoyu and Zhu Yuan in Chap. 22 and Martin Meganck in Chap. 23 explore more philosophical and spiritual backgrounds of the way technological development can be understood in Chinese culture and in cultures with a Judeo-Christian tradition, respectively. Chapter 22 argues that Chinese traditions offer conceptual resources and ethical principles for ecological thinking, seeing humanity as an intrinsic part of the natural order. In Chinese tradition including Confucian, Taoist and Buddhist philosophies, the relationship between humans and nature is based on the idea and ideal of harmony. Here a holistic view prevails, in which man is only part of the whole. Wang Guoyu and Zhu Yuan describe how this model of harmony expresses itself in ancient agriculture, handicraft and medicine.

Meganck's point of departure in Chap. 23 is Lynn White's famous and influential article *The Historical Roots of our Ecologic Crisis* published in 1967, in which the ecological crisis is said to have its roots in the Judeo-Christian backgrounds of Western culture. According to White, the Judeo-Christian worldview is highly anthropocentric thus putting human beings at the centre of the universe. Nature in contrast is disenchanted. Mankind can thus engage in an unbridled conquest of nature. As a reaction upon the accusing tone of White's article, many thinkers rushed to the rescue of Christianity's reputation. They criticised or mitigated White's interpretation and referred to the idea of *stewardship* instead, which is also present in

Christian tradition. Yet it seems that at least in the past, man's domination of nature was often legitimised by making use of biblical or Christian theological arguments. Surveys on how people actually see nature nowadays present us with a more diverse and nuanced view.

Part III begins with Chap. 16 by the French sociologist Christelle Didier. She traces back what became of engineers once engaged in *Engineers without Borders*. At first sight it would seem that some of them returned to "ordinary" engineering work, yet it appears that – more than most other engineers – they tend to remain engaged in associations, NGO's and the public sector. But even before their *Engineers without Borders* period, they had a somewhat deeper affinity with churches, unions or other social organisations. Like the wide-ranging philosophical, cultural and political circumstances influencing "engineering", which have been illustrated in the other chapters of this part, also the individual environment in which people are socialised can have a major impact on their personal values, beliefs and professional development. Coming full circle, the idea of Didier's chapter is thus not only to trace the impact of first socialisation on engineers' career choice and their commitment to social issues (such as development). It also becomes clear that engineering education and professional socialisation are a question not only of curriculum but of early experiences made possible by and increasingly encouraged in the engineering school environment.

One of Karl Popper's criticisms against empiricism in philosophy of science was that verifications can be found for almost every theory believed in. To what extent therefore do individual examples or specific cases prove anything, even if several of these examples or cases can be shown to have common characteristics? This question is relevant for the interpretation of ideas developed within this section. Are the examples of harmony-oriented versus domination-oriented man-nature relationships as presented in Chaps. 22 and 23 sufficient to prove these views? Or are they just selective examples to illustrate them? Asking in the same vein, can the examples of railroads, dam construction or leadership roles thus also be randomly selected to illustrate a certain view? Or do they point in a common direction? We believe the examples are significant even if we are well aware of the necessity of a critical and cautious reading.

There may also be tension between the analysis carried out by philosophers and the actual conscious experience by people themselves. To the extent that it is philosophy's task to bring to surface underlying presuppositions of people's actions or thoughts, this should not be surprising. Yet this may lead to an attitude where philosophers or sociologists pretend to know or understand better what and how people think than the observed people themselves. In many cases, this may be true. On the other hand, like other scientists who are supposed to show humility when confronted with facts, philosophers and sociologists too should be open to the challenge of views which are not perfectly in line with their analyses. Even if strict falsifiability may not always apply, intellectual honesty requires at least to abstain from dogmatism or fundamentalism. For this section, this may particularly apply for the chapters where technological development is framed in the larger philosophical contexts of Chinese or Judeo-Christian traditions respectively.

The philosophical analysis is further challenged by the influence of very concrete and often contingent historical, political or economic facts, like wars, economic crises or changes of political regimes (be it as a result of revolutions, of elections or other national or international events). In this section, these influences can be felt in the studies of railroad and dam construction, industrial heritage conservation, leadership roles of engineers or policy calls for the integration of socio-ethical considerations in science and engineering R&D activities. Of course, these discrete historical events are not completely independent from the more fundamental and ideological currents in history. The establishment of causal relationships however is not always unequivocal and one-directional. One example: how do recent developments in Chinese society relate to traditional Chinese culture as described in Chap. 22? Some may consider Western influences to be the main driving force behind the development of contemporary Chinese society, through either the Western roots of Marxism or the Western elements of capitalism and industry. And yet, traditional Chinese culture remains present everywhere. Related to this omnipresence of traditional Chinese culture, a second intricate question is to what extent if any do traditional Chinese values affect the meaning of "Made in China"?

It is not unusual for academic literature to raise at least as many questions as those for which it is able to give answers. We believe that the chapters of this part can provide food for reflection on engineering, nature and society. And that was what they were supposed to do.

Chapter 16
Ex-students Engaged in "Engineers Without Borders": What Have They Become?

Christelle Didier

Abstract The engineers' ethos can be explained by the composition of the population (mainly male, highly educated, at ease with science and coming from upper middle class families). But this ethos is also influenced by the graduates' secondary socialization in the engineering education and whilst at work. In this chapter, the author sets out to investigate the influence of the involvement of engineering students in a development-oriented association on their career path. The research is based on a large number of ex-members of the association "Engineers without Borders" in France. In this chapter, the author analyses by means of online CVs and interviews with ISF present-time staff current the professional path of a few main figures of the 30-year-old association.

Keywords Engineering ethics • Career path • Development issues • Student commitment • Engineers without borders

Introduction

Ingénieurs sans Frontières (ISF Engineers without Borders)[1] has been, since its creation in France in 1982, an organization where French engineering students have had the opportunity to discuss the social usefulness of their technological knowledge and skills and reflect upon sustainable development issues. Since its creation, the association has offered its members the opportunity to complete their

[1] Other student associations have carried this name since 1982, and many of them have gathered in an international network. Although all concerned with international solidarity, they do not share exactly the same goal nor work in the same way (Lamb 2010). For a better understanding of the humanitarian context of engineering (Mitcham and Munoz 2009).

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education with a volunteer and militant experience in the field of international solidarity and attend training on development issues. With 38 local groups in 80 engineering schools, ISF aims to enhance the engineers' social responsibility. Next to the organization of development projects, the association organizes debates and questions the role of technology in the context of developing countries and the issues of sustainable development in developing as well as in developed countries. Campaigns are also set to disseminate ISF ideas and try to influence both national and international authorities. All ISF actions are prepared in collaboration with other actors of the civil society (Derouet and Paye 2009). Today and since the adoption of its latest charter in 2002, its slogan is "give a meaning to technology for a better world".

A survey conducted by the association among its ex-members in 2000 shows that while 37% of the population considered their commitment as students had an influence on their career and professional choices; this was the case for 50% of the respondents who had been the most active at ISF (and only 17% of the least active ones). Rodolphe Rosier, a national vice-president from 2001 to 2003, and Pascal Bousso, in charge of the ISF journal, stated that the ex-members who considered an influence of ISF were not working in the same type of companies as the others: they were more often in the public sector, nonprofit organizations or NGOs (Rosier and Bousso 2001). Only 50% of them were working in private companies, while it was 60% for those who declared "noninfluence". As a comparison 83% of French graduate engineers declared a "non influence" according to the survey we conducted the same year (Didier 2008, p.107).

The objective of our ongoing research is to deepen the reflections ISF started with this survey. Beyond that, our aim is to question the role a student association can have on the engineers' ethics.[2] Rather than analysing what the engineers assert about their ethics,[3] we have chosen to study concrete decisions among the most important of their professional lives, i.e. what concrete job to do and in which organization to work. Through semi-directive biographical interviews with former active members, we intended to analyse their professional trajectory and identify the factors that may have weighed on their decisions and, among them, the influence of their commitment to ISF during their studies. At this stage of our research, we have first gathered in 2010 from various public sources a series of information about more than 50 ex-ISF members (30 active members at the national coordination and 20 other members having had various levels of involvement). Second, we have completed this with interviews of two present-day officials at the national federation.

[2] ISF appears to us as the sole French engineers-only association to defend not only in words, as most codes of ethics do, but also through very concrete actions the ideal of a socially responsible engineering.

[3] This was the objective of the extended survey we conducted in 2000 with 3,901 engineers (Didier 2008, 2009).

A High Professional Ideal Embedded in Codes

To be in accord with one’s values at work is far from being easy for an engineer. As far as professional (and not only personal) values are at stake, this consistency is not easy to achieve, because this ideal is rather high. Although there is no unique code of ethics for the whole engineering profession, and although there are even countries where such codes do not exist or have little meaning, like in France, those documents offer a rather good picture of the ideal mission articulated by the engineering profession (Didier 2010). Most of the current codes of ethics, like the one of the National Society of Professional Engineers in the USA or the one of the American Society of Consultant Engineers, state that the engineer “shall hold paramount the safety, health and welfare of the public”. These professional obligations remind us that technological development is a risky enterprise and may have negative social impacts. Moreover, those codes attest that the engineering profession is well aware that technical progress and social progress do not always go together. Considering engineering as being in itself a humanist enterprise may be an ideal for some,[4] but it does not correspond to reality.

In 2001, the World Federation of Engineering Organizations’ model code of ethics proposed that engineers take into account “the protection of both the natural and the built environments in accordance with the principles of sustainable development” (WFEO 2001). In 2002, the Association of German Engineers (*Verein Deutscher Ingenieure*, VDI) stated in the conclusion of its “fundamentals of engineering ethics” that “engineers are committed to developing sensible and sustainable technological systems” (VDI 2002). In 2001, the French National Council of Engineers (*Conseil national des ingénieurs et scientifiques de France,* CNISF) wrote, in the lastest version of its code of ethics, that “the engineer is a responsible citizen who is in charge of connecting science, technology and the human community” and who “bases his action on the principles of sustainable development” (CNISF 2001). Those code articles do not only emphasise the duty for engineers to avoid the negative side effects of technological development but they also go much further. Indeed, for an engineering project to be in accord with the principles of “sustainable development” means more than just avoiding unexpected (or well-known) social and ecological bad side effects. It suggests referring to a pattern of resource use that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Commission 1987). Sustainable development does not merely imply an obligation to reduce social and ecological impacts resulting from the way we meet our present needs. It also challenges our so-called present needs.

According to the guidelines of WFEO, VDI and CNISF, the “ethical engineer” should not only be a cautious professional responsible for the consequences of his

[4] Like Eugene Schlossberger for whom engineering is not “just a job”, but “a calling”, a moral commitment and who defines “the engineering way” as being in itself “precise, rational and careful” (Schlossberger 1993, pp. 41–42)

decisions and actions. He or she should also be a professional whose goal is to endeavour to meet the current needs of our world, not only the requests or their clients, managers or employers. Do the authors of the ethical documents we studied expect engineers to share the highest goal of sustainable development and identify "meet our needs" with "achieve the *fundamental* needs of the whole humanity"? Considering the close relationship between UNO and WFEO, we tend to believe that the intention of WFEO's model code is to support this broadening of the scope of engineers' social responsibility. We are less certain that VDI and CNISF, which are above all meant to defend the engineering profession's interests, share exactly the same vision.

Ethical professional values shared by engineers are not visible only in the codes of ethics published by their official professional organizations. Other places and other discourses need to be studied, coming from engineering student associations, trade unions and other technical and scientific associations rather than the main official ones. To give a few examples, we can quote "the Hippocratic oath for engineers" suggested by Professor Meredith Thring in 1969 in Czechoslovakia at the International Symposium of the Federation of Scientific Workers. The first sentence of this oath was "I swear that I'll do my best to use my professional competencies exclusively to projects that, after reflection and according to me, contribute to the pacific coexistence of all humans, to enhance human dignity and personal fulfilling". Concerning students' initiative, we can quote the "new Archimedes' Oath" published in 2000 by the *Institut National et Polytechnique de Grenoble* in France which says in its 3rd article: "I vow to promote the respect of equity between all humans and support the development of economically underprivileged countries". The story of the "pledge of ethical conduct" that was printed in 1997 for the commencement programme for the College of Engineering at the University of California is also very informative. The Student Pugwash Chapter had proposed a very committed text written, with the sponsor of Joseph H. Wujek for the 1995 Nobel Prize ceremony.[5]

This pledge said:

> I promise to work for a BETTER WORLD where science and technology are used in socially responsible ways. I will not use my EDUCATION for any purpose intended to harm human beings or the environment. Throughout my career, I will consider the ETHICAL implications of my work before I take ACTION. While the demands placed on me may be great, I sign the declaration because I recognize that INDIVIDUAL RESPONSIBILITY is the first step on the path to PEACE.

The text that was finally adopted after several rounds of negotiation with the student relation committee, the engineers' joint council and several student societies of the college is rather different and borrows heavily from the IEEE code of ethics. It says:

> We, graduating from the engineering class of 1997, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members, and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct. Throughout our

[5] The Prize was attributed that year to Joseph Rotblat and Bertrand Russell who founded the "Pugwash Conferences on Science and World Affairs" in 1957 in order to bring together influential policy officials and scientists to seek towards eliminating nuclear weapon and reducing the threat of war.

> career, we will consider the ethical implication and the impact on safety, health and welfare of the public and the environment of the work we do before we take action. While the demands placed upon us may be great, we make this declaration because we recognize that individual responsibility is the first step on the path to a better world for all.

This change from the original proposition of 1995 shows first that the universities are not ready to go too far in defining the engineers' moral responsibility. It also shows that there are among engineering students young people who share a high ideal, believe that engineering can be a humanly and peace-serving enterprise and that to be an ethical engineer does not only mean to be cautious.

What Have They Become?

Early Times

Thierry des Lauriers was the first president and one of the two founders of the first association to bear the name "Engineers without Borders" in 1982. Today, he works as the general manager of an association called "*aux captifs la libération*" (release the captives), a Catholic home for street people, prostitutes, transvestites, young adults and homeless people where they can get listening, guidance and help. This association is composed of 170 volunteers and 50 salaried employees who work together with four Catholic parishes in Paris (Viadeo). His job in the charity field is rather new (9 months old in 2010), and he is also a management consultant at "Reflexive Partner". His two previous jobs were already in consultancy. From 1997 to 2007, he was at INSEP consulting where he ended up as associate director; then from 2007 to 2010, he was the managing director of "Sustainable" where he published two books ("Success of your Business Plan" and "Project Management" at INSEP consulting). His previous and second job in his career (from 1985 to 1991) was in industry, in the field of metallurgy where he started as financial controller and ended up as production manager (in charge of 120 people). His first job after graduation, from 1983 to 1985, was for the French Ministry of Urbanism in Ethiopia, which is the country where ISF took up its first challenge.

At an age of 51, Thierry des Lauriers is no longer committed to ISF: he is neither a member nor a resource person or a donator. On the online CVs that we have consulted on two business-oriented social networking sites (LinkedIn and the French "Viadeo"), his past with ISF does not appear, neither in the description of his career nor among his extraprofessional interests. Still, we have found two documents in which he presented himself as the founder and first president of ISF on the Internet.[6]

[6] On the webpage of "Sustainable", each member's career is described. The article on Thierry des Lauriers, still readable in 2011, states that he founded ISF in 1982. We also found an open letter to President Nicolas Sarkozy that he signed in 2009 as the managing director of Sustainable, "president founder of *Ingénieurs sans frontières"* and member of "*les semeurs de communions*" (a Catholic movement). The letter was about Christian values and the twenty-first-century's economic challenges.

So how did he happen to found ISF and what can we say about the influence of this commitment as a student on his career?

In 1982, Thierry des Lauriers was in his second year (i.e. the 4th after high school) at the *Ecole Nationale des Ponts et Chaussées* (ENPC), one of the oldest and to this day the most prestigious and selective school of engineering in France. The young tutor, Philippe Mahrer, was asked by one of the main French NGOs involved in development aid to provide technical assistance for a water drainage project in Ethiopia. He was himself an administrator of "*Action contre la faim*" (Action against hunger). Two students joined him to take up the challenge: Thierry des Lauriers and François Friggit.[7] Knowing the existence of *Médecins sans frontières* (MSF, Doctors without Borders) created by physician Bernard Kouchner in 1971, they looked for a similar structure to accommodate their project and discovered that there was no such association in France. They decided to found it and named it after MSF: ISF for "*Ingénieurs sans frontières"* (Malleret and Bourgey 2007). The first association was composed of engineering students of the ENPC only. Soon, other local groups started in other engineering schools gathered in a national federation: there were 20 local groups after a few years and 38 by 2010. Similar associations of engineering students interested in international solidarity were created abroad afterwards, like "*Ingénieurs sans Frontières*" (today called ISF-ASI, International solidarity action) founded by students of the Catholic University of Louvain, in Belgium (Martin Meganck 2010), or "*Ingenieros sin frontera*" which was created in 1992 by students who had met ISF students in France during their Erasmus exchange and is today the biggest Spanish NGO (Francisco Javier Cañavate Ávila, and Josep M. Casasus 2010). Erasmus is a EU student exchange programme established in 1987.

Between 1982 and 2010 of ISF France, the association went through changes and dissensions (Simon Paye 2010). In its first period, it developed from a small association of engineering students, amateurs in humanitarian help. After a few years, it became a large NGO specialized in development aid engineering. From 1990 to 1999, a large debate took place in ISF on its "professionalization", as in many NGO and international solidarity associations at that time. One of the dilemmas was to increase or not the permanent staff, to get involved in more ambitious projects and appeal for support from more sponsors. In 1995, ISF opted for more professionalization, recruited its first permanent staff and got involved in some major long-term projects. Simultaneously, another mission of ISF developed which Simon Paye translated as "awareness raising in development issues" ("*éducation au développement*"). At the end of this decade, two visions were conflicting: some members were favourable to maintaining the status quo and considered ISF as a "professional" development aid engineering association. Others advocated various goals. They argued for more awareness-raising campaigns, political involvement and grassroots

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[7] On LinkedIn, François Friggit presents himself as "managing director, front office 'quantitative analyst'" specialized in "complex financial products based on sophisticated mathematical models". Graduated from Polytechnique, ENGREF and HEC school of management, he worked for different banks in Paris, New York, London and Madrid and previously for 5 years in West Africa as an engineer.

activism. The professionalization bet, i.e. the attempt to give up the amateurish student-only approach, did not last, and ISF went through an identity crisis. Since 2000, while development projects are still organized by local teams of students and evaluation and training organized by the national coordination, ISF has also become a social movement of engineering students concerned with ethical issues, questioning the meaning of technology as well as the social role of the engineer. A slogan has been developed over this last period: "*ingénieur citoyen*" (literally "citizen", in English, which would be better translated as "socially responsible" engineer).

In 2007, Thierry des Lauriers answered to Gregoire Bourgey who was at that time president of ISF in a special issue of the association's journal dedicated to its 25th anniversary. He explained that in the 1980s, ISF had three goals: firstly, to provide technical assistance; secondly, to broaden the engineering students' understanding of development issues; and thirdly, to make them aware of their professional responsibilities (Malleret and Bourgey 2007). Gregoire Bourgey asked him to react to one of the new topics discussed at ISF on whistleblowing and related questions. The answer was that one should learn first to "say things positively" and ISF should, rather than focus on problems, highlight best practices as the association "Ashoka" does.[8] Clearly, the first president did not feel in full agreement with what ISF had become lately. Although our hypothesis should be confirmed in the interviews we scheduled for the second step of our research, it seems to us that his actual involvement in a charity devoted to the less privileged is very much linked to a long-lasting commitment in Catholic charismatic movements (a kind of Catholic Pentecostalism), which may well date back to an earlier period than his studies, maybe his primary socialization. His religious engagement may also have led him to accept the challenge of the humanitarian project in Ethiopia and the creation of ISF that followed.

Among the early ISF members, we have identified a few other people rather different from Thierry des Lauriers. Benoît Heitz (like des Lauriers) graduated from ENPC, be it a few years later. At 47, he is someone no one had heard about at ISF until he talked about his past with ISF to a journalist of figaro.fr, one of the top news websites in France, in 2007: "*Benoît Heitz (Eiffage), de l'eau pour un village éthiopien* (water for an Ethiopian village)". Benoît Heitz was then the managing director of Eiffage, the third biggest construction company in France with 58,000 employees. He entered the company in 1987, just after his graduation and never left until 2008. From 1996 to 1999, he was first a director then a manager of Walter Bau in Germany, and from 1999 to 2001, he was general manager of SAEP within Eiffage construction. He was appointed assistant general director of the electricity branch of Eiffage in 2001. From 2004 to 2007, he was the European director of the group, which ranks among the major European construction industries (*Les échos*, 9/9/2005). In December 2007, he resigned as managing director of Eiffage, just 8 months after taking up the job (2 months before the interview), officially for "personal reasons". This chapter is not a place to discuss the reasons why he may

[8] Ashoka is an international nonprofit organization supporting the field of social entrepreneurship.

have been asked to resign after a successful 20-year career in the same company. Since then, he has run his own business together with another former high-level colleague in the same business area.

Indeed, Benoît Heitz's career is very different from Thierry des Lauriers's, although they have in common a graduation from the same prestigious school and an experience with ISF in Ethiopia. In the interview to figaro.fr, Benoît Heitz explained that he had chosen ENPC in his youth because it was the best among the engineering competitive exams he had passed. He also said that the years he spent as an engineering student were a very good period in his life. Between his first and second year, during summer 1985, he went on a humanitarian mission to Ethiopia with another student, stayed in a village for 3 months, shared the life of the villagers and helped to build a device to collect rainwater to water the fields. "It was physically a difficult experience, because of the insects, but very enriching humanly", he said. When asked for the reasons for going to Africa, he answered, "a sense of adventure".

Among the early ISF members, three of them contributed to the creation and early steps of the local group at HEI (*Ecole de Hautes Etudes d'Ingénieurs*) in Lille, a Catholic 5-year-course engineering school where students enter directly after high school. Those three people are not known among the current ISF coordination team, but do belong, as many others, to the history of the association. Vincent Blin, 47, graduated in 1989. From 1985 to his graduation, he took part in six projects and organized a whole week on international solidarity (*HEI news*, n°16, 1987). After his graduation, he went on a cooperation mission in Chile for 3 years. He has always been very committed to an association fighting against torture, called ACAT. Today, he is a Catholic priest. Etienne Lerouge, 46, graduated from HEI in 1987 and got involved in ISF during his last 2 years (which were the two first one for ISF-HEI). He followed a more typical road for a graduate engineer, worked as quality manager in a smelter plant, then from 2000 to 2004 at one of Renault's main bodywork assembly plants and then in the Slovenia factory of the car manufacturer. In 2004, he took over the management of the small company of hydraulic and industrial bodywork started by his father in 1987 (*Envie Roncq*, 2007). Four years later, he almost doubled the number of employees. Abdourahamane Diallo, 43, graduated in 1991 from HEI and also took part in ISF early projects. Since 2009, he has been the head of the Brazzaville office of UNESCO in Congo.

Active Members of the 1990s

In 1997, the journal "*Economie et humanisme*" published a special issue about ethics and the engineers' responsibility. One of the articles was written by Vincent Pluchet (graduate from *Ecole Polytechnique* in 1990 and ex-president of ISF France) with the help of Olivier Chabrol (ex-ISF vice-president, in charge of development projects) (Pluchet 1997). We did not find much information about Vincent Pluchet who was ISF President and in charge of the journal in 1995 and 1996: he is not in touch with the national coordination anymore. He has been working for AXA since 1993 Olivier Chabrol started his career in the petrol industry. He joined the campaign "*L'éthique sur l'étiquette*" (ESE, French Clean Clothes Campaign, carried out by ISF) in which he led the social label programme of the international retail group Auchan in Madagascar from 1997 onwards. He also founded an association called Djembé whose goal was to propose responsible tourism in the Ivory Coast. He has been working for ESE until recently. Today, he is working as an expert and advisor on corporate social responsibility for trade unionists and employee representatives at Syndex (consultancy and technical assistance for trade unions).

Graduating in 1995, Pascal Bousso went with Lionel Trottet, today a researcher at GSK in France, to Cambodia with the novel status of long period volunteers that ISF experienced from 1995 onwards, with the financial help of companies like Pechiney, French leader of the aluminium industry then (*ISF journal*, n°30).[9] His mission was to support a water drainage project carried out by two local ISF groups. From 1997 on, his commitment to this project continued through the creation of a Cambodian NGO called NAS, where he is still active today and which Lionel Trottet keeps on supporting financially. Eager to share his experiences and reflections, Pascal Bousso co-authored books and wrote articles about rural credit and organic rice in Cambodia (Bousso et al. 1997; Bousso 2006). He gave speeches about NAS to students in local ISF groups and wrote about his experience as a volunteer who turned "militant" (2003). Since his engineering studies, he has been committed a lot to ISF, through his mission as a volunteer, various positions he had in the national Board and his active participation in the journal. Still considered by the current ISF team as a resource person, Pascal Bousso is working now in a rural region of France (Creuse) in a publicly funded institution in charge of supporting and accompanying the development of socially useful activities. He is also involved in politics, supporting the ecologist party.

In 1995, for the first time in its history, the election of ISF's national president led to the opposition between two lists of candidates. The first one who was in favour of more professionalization won, and Nathalie Schnuriger, a graduate from the chemical engineering school of Paris in 1993, became the first (and only one, to date) female president of ISF, from 1995 to 1998. Although a very active president, who initiated the new status of the long period volunteer and increased the number of sponsorships from companies and the public sector, she had not been in contact with ISF for some time. One of the reasons is that she has been living in Cambodia for 10 years where she created the foundation "*France-Pays du Mekong*". She came to the 25th anniversary of ISF in 2007 with her husband she had met at ISF when students. Still, she continued to have professional contacts with the association, until recently, through her job as project manager at the French Committee for

[9] Pechiney offered 500,000 francs in 1993 to ISF for two development projects in Mali and Togo. (Alternative économique, n° 109, 1993).

International Solidarity, which is a very close partner of ISF. Today, she is 41 and a mother of four; she declared to a journalist at leparisien.fr (21/07/2010) that when she discovered what her children were eating at school, she commenced her "food revolt" and decided, after 15 years working in the field of international solidarity, to start a small business in the field of locally produced organic food distribution. She joined a federation of small company sharing the same values, called *Solidarité Enterprises Nord Sud* (SENS which is the French word for "meaning"). SENS is the partner of an ISF local group, in her hometown.

At the 1995 election, Yannick Lechevallier opposed Nathalie Schnuriger, defending another project direction for ISF as a student-only association. Graduated from the *Institut national Polytechnique de Grenoble* (INPG) in 1995, he was in charge of "development issues education" at ISF. After his graduation, he carried on his studies with a professional master's degree on "humanitarianism, development issues and cooperation" which was then the only master's degree specialized in international solidarity in France. In 1999, he went to work at *Cités Unies France*, an ISF partner association which brings together French local authorities involved in international cooperation. It was for him a kind of "professional activism", as he said in a paper for the ISF journal (2001, n°49, p. 20). In 2002, he created his own business in the cooperative sector as a consultant in decentralized cooperation for public sector institutions. From 2005 to 2007, he was the president of the association of young experts in development and international cooperation. Unlike Nathalie Schnuriger, he is still in touch with ISF's current team. Actually, the association followed the project he was promoting in 1995. Although not very available, he is considered as a resource person, interested in what ISF is doing in many fields. He offered the first training about decentralized cooperation for ISF members in 2006 and then again in 2007.

The next president, after Nathalie Schnuriger, was Bruno Valfrey-Visser, 41, who graduated in 1993 from ENSMA (Mechanical and Aeronautical engineering) Poitiers and holding a master's degree in physics. He experienced ISF, at the top of its professionally oriented period, as a place to prepare a career in the field of international solidarity. As a student, he took part in a long-term volunteering, from 1991 to 1993, in Western Africa and was in charge, from 1993 to 1995, of a 2-year water supply and sanitation project in northern Senegal, both for ISF and as a member of the *Association Française des Volontaires du Progrès* (financed by the French Ministry of cooperation). He joined in 1995 Hydroconseil and is today the managing director of this consulting firm specialized in the modernization of water utilities and the improvement of services and coverage in low-income urban areas in developing countries (LinkedIn). The present director of Hydroconseil's Paris office is Antoine Malafosse, 46, a graduate from ENPC, ex-ISF vice-president then president (1983–1985), administrator (1987–1990) and first salaried employee from 1990 to 1994. His previous job, before Hydroconseil was, from 2007 to 2010, as managing director of *CCFD-Terre solidaire* (Comité chrétien contre la faim et pour le développement), the largest French NGO in the field of development aid (500 projects per year supported in 70 countries).

Active Members of the 2000s

After Nathalie Schnuriger's presidency, ISF went through a kind of crisis and questioned its mission. For this more recent period, some ex-presidents and active members have chosen to work in the field of international solidarity, like Christophe Alliot who is the strategy coordinator for the international alliance of fair-trade producers. His previous job was as deputy director at Max Havelaar France, a long-time partner of ISF co-founded by ISF with other NGOs in 1992. Graduating from ENSAM (*Arts et Métiers*) in 2000, and also in Political sciences, he was the president of ISF from 1999 to 2002 and enabled ISF to overcome its identity crisis and find its new breath and mission. During his presidency, he has been working for one year at Schlumberger, in the human resources department, and then at Atos consulting. When the major public and private sponsorships ended together with the opportunity to hire conscientious objectors, Christophe Alliot took a year's leave to work as a full-time volunteer for ISF. He was a board member until 2007 and is still considered as an essential reference for the association. Other ex-active members chose careers away from international solidarity, like Rodolphe Rosier, vice-president in charge of "development issues education" from 2001 to 2003. Graduating from ENPC in 2001 and with a Phd in business administration, he worked as a business developer and is today a business consultant in international strategic management. He is not in touch with ISF anymore.

Samuel Foutoyet has a rather original profile. Graduated from INPG in 2002, he never got involved in the national coordination, but was a very active leader of a group of students promoting humanities in engineering education in Grenoble: he is the author of a six-page document added to ISF's 2002 annual report and of another document published in 2003 and completed in 2005.[10] Samuel Foutoyet is not in touch anymore with ISF today, but he was interviewed for the ISF journal because of his very atypical career in 2009 (Paye 2009). After a few years as an engineer at the *Companie Générale des Eaux* (today Veolia Water, the world's largest water supplier) in order "to understand capitalism from inside", he quitted, "disgusted by his employers' methods", and took a sabbatical year. He joined an association called "*Survie*" (survival) which denounces the neo-colonialist attitude of French governments towards some African countries. The founder of Survie labelled this attitude "*Françafrique*" and explained his position in ISF's journal in 1995, as well as in many books he has published since then. Samuel Foutoyet's first book, *Nicolas Sarkozy ou la Françafrique décomplexée,* was published in 2008. He is today a full-time radical activist. ("*Fric*" which sounds like "(A)*frique*" means money in French slang.)

Vice-president in charge of development projects, Simon Godefroy was elected president after Christophe Alliot from 2002 to 2005. Like him, he was a charismatic president. A board member until 2010, he is still considered as an essential resource person for ISF. Graduating from the *Ecole Centrale de Lille*,

[10] Available on the website of the ISF project "Former l'ingénieur citoyen (educate a socially responsible engineer)" (http://formic.isf-france.org)

he has been a software engineer at *Electricité de France* (EDF), the world's largest utility (public establishment until 2004). Recently, he has been posted by his company to the association "Service Public 2000" as an expert and advisor in public management for local authorities. As a student, he was very active in one of the large projects carried out by ISF in Kanel, Senegal. When he was ISF president, his company seconded him part-time at ISF to achieve his task at ISF. Until today, he has been involved in unionism at CFDT-Cadres, a major partner of ISF on the recent topic of social responsibility and whistleblowing. His friend, Maxime Chodorge, 35, who graduated with him from the *Ecole Centrale de Lille* in 2000, completed his education with an MBA in administration statistics and became an expert in charge of economic studies for the national federation of affordable housing. He has been very close and very committed to ISF until recently as a board member in charge of the theme of "energy".

Graduating from ENSAE (Aeronautic engineering, Toulouse) in 2002, Maël Guennou was president in 2006 and a board member for 3 years before and again in 2007. Today, he is a PhD student in physics. Still very active for ISF, he is in contact with its staff members every other week and helps with the accounts. In 2003, he joined the first ISF group of "graduated engineers-ex-ISF engineering students". Vincent Gautier, who graduated from the *Ecole Centrale de Nantes* in 2003, was in charge of this group (called "Paris VI") from 2005 onwards after Christophe Alliot who had created it. He explained in 2005 that its members felt a large gap between their shared values and their companies. One of their expectations at that time was to organize training sessions to help them deal with conflicts at work and assist them in introducing their interest in international solidarity within their workplace (email: 23/09/2005).

When Jean-François Cassagnau joined ISF, he thought he would go to Africa and dig wells; he did not expect ISF not to be the place for that.[11] In fact, he never went abroad for a development project, but instead got involved in his local group and then in the national coordination in 2001 and 2002. At that time, ISF was questioning its missions and goal, with the wish to move from an association which organizes development projects to an association working in a partnership rather than an assistance perspective. He was "very interested in this question and got committed a lot". Why did not he look for a job in the field of international solidarity? "I was maybe not committed enough, not as much as some others, but still, I was more involved than the average (…). I had a keen interest in my studies. Honestly, I never wondered if I should work in international solidarity". Still an ISF member and always there at the annual general meetings, Jean François Cassagnau joined the group "Paris VI" in 2005.

The last president we chose to describe is Grégoire Bourgey, 31. He graduated from the *Ecole Centrale de Nantes* in 2004 and became president in 2007, the year of the 25th anniversary. Still considered as a resource person for the ISF staff today, he is working at Lafarge, the world's largest cement manufacturer. He is working

[11] *Altermondes,* n°11, Septembre 2007, Dossier 11 "Trop jeunes pour changer le monde?" – Too young to change the world? (http://altermondes.org/spip.php?article232)

far from development aid and has always considered his commitment to ISF as something next to his professional life.

Conclusion

Do ex-ISF members differ from other engineers? Do they bear witness to a more responsible way to practice their profession? Did joining a humanitarian student association have an influence towards a more socially responsible career? A survey set up by ISF in 2000 showed that the former members (at least those who answered) were more likely to be working for the public sector, NGOs or associations than the average graduate engineer. And this was all the more true as they had been involved in the association. Our study seems to show that being involved with ISF had an influence on the career path, at least, for the most active ex-members.

The present study is the starting point of an ambitious research project about socially responsible engineering. Our main goal is to study the career path of graduates who use their engineering skills in a job devoted to "work for a better world", as the Student Pugwash Chapter assessed in their 1997 pledge. Our aim is also to identify what may lead a graduate engineer to choose the narrow road of (a militant type of) socially responsible engineering. Our statistical studies about the engineers' ethos (Didier 2008) made us aware of the impact of the social origin, the gender and the generation on the graduates' ethics. The present study about ISF ex-members intends to fill a void about the impact of the students' commitment in humanitarian associations.

Although joining ISF may be seen as an opportunity to be acquainted with social responsibility issues, this choice may be founded for some students on the wish to put into practice pre-existent personal values (social, human or religious). The stories of the first president and the first staff member illustrate this point: both of them have been very committed professionally in confessional organizations, recently for the former and for many years for the latter. Of course, such a decision can be the consequence of a late conversion, but we cannot exclude the possibility that it is founded on their primary socialization (rather than their experience with ISF). Still, we can make the hypothesis that they joined ISF because it was consistent with their values. If we think of other highly structuring values, we can wonder if the ex-members who are strongly committed today to unionism and politics were brought up by parents themselves interested in politics, because statistics show a rather low interest of graduate engineers in politics in general in comparison with other professionals. If we want to understand the influence of the students' commitment on their professional choice, we need to study the reasons why they joined ISF, what they expected from it and what it meant for them.

Some ex-members have had the opportunity to answer to journalists for a newspaper or colleagues for a students' magazine to questions about their commitment to ISF. While one of the early members expressed without hesitation that he joined in to live an "adventure", two more recent ex-members expressed that they joined in with the belief that they would “dig a well in Africa”, but soon understood that ISF would not be the proper association for “humanitarian tourism”. If ISF was in the 1980s, the only engineering student association involved in development aid, there are many of them involved today. Still, although it has renounced to become a “professional” development aid association, ISF remains a very demanding association for its volunteers, with its compulsory trainings sessions at weekends, and also because very few students go abroad “to dig well” while many of them are requested to prepare the mission beforehand and evaluate the missions afterwards. If some students joined out of curiosity, those who remained and particularly those who carried on after graduation, within the national coordination seem to have experienced more than exoticism. But being a member of ISF does not mean the same to everyone. Moreover, it does not mean the same according to the period when this involvement occurred. It is noteworthy that most of the former active members who joined ISF in its “professionalization” period became professionals in the fields of development aid engineering. ISF was not for them a means to put values into practice, at least not only this but also an opportunity to gain their first professional experiences. Many of the ex-active members we quote ended up in one of the ex-partner professional associations. Some of them created their own business later in the same field.

In its latest period, ISF left aside the professionalization track. The association also lost, for ideological as well as financial and institutional reasons, the opportunity to conduct major projects and offer students or young graduates (with the status of conscientious objectors sometimes) a true professional experience in development aid. University degrees in this field were created and ISF got involved in other issues such as fair trade or sustainable development. The association developed a new major project called “the citizen engineer” to help graduates prepare for socially responsible careers within more “typical” jobs and companies. Among the active members of this latest period, some graduates became professionals in the field of social responsibility, not only in development aid but also in various other areas such as fair trade, sustainable development, local development and unionism. But it is worth pointing out that some very committed ex-members (presidents as well as vice-presidents) opted for a more traditional career. While some of them left a typical engineering job after a few years to use their skills elsewhere, others have continued until now in their engineering area. For them, ISF may have been an association allowing them to put into practice their pre-existent values and also to be better informed and trained in social and development issues. But they have not prepared themselves to become “development aid” or “corporate social responsibility expert” engineers. Hopefully, their involvement may have contributed to help them become more socially responsible engineers in their workplace. The next step of our research, through the interviews we intend to conduct, should help us understand better not only the motivations to join in, the meaning of this experience as students but also the impact on today’s professional life, whether in a typical or atypical type of workplace.

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Chapter 17
Socio-Technical Integration: Research Policies in the United States, European Union, and China

Hannot Rodríguez, Hu Mingyan, and Erik Fisher

Abstract Research policies in the United States and the European Union have shown increasing eagerness in the last two decades to incorporate insights from publics and the human and social sciences into natural science and engineering research, while Chinese research policies devote relatively little attention to socio-technical integration. The ELSI (Ethical, Legal and Societal Implications) program of the US Human Genome Project functioned primarily as a parallel exercise with little real influence on genomic research practices, but more recent research policies for nanotechnology go as far as to redefine research and development in this field as a confluence of technological and societal research. In the EU, the Framework Programmes for Research and Technological Development show a progressive radicalization of integration discourses and practices. ELSA (Ethical, Legal and Social Aspects) research, for example, which has been conducted since the 2nd Framework Programme (FP2, 1987–1991) in parallel to the natural science and engineering research it studies, has been conceived as a constitutive part of science and engineering research projects since FP6 (2002–2006). Although there are few formal Chinese science and technology policies that encourage socio-technical integration, more and more Chinese scholars from both natural and social science and humanities have embraced the idea of integrating social and ethical concerns at an early stage of science and technology development.

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Introduction

High expectations and societal concerns surrounding the heavy investments in new and emerging technologies have opened policy discussions about the roles of humanists and social scientists in national science and technology programs around the world (e.g., Barben et al. 2008; Bennett and Sarewitz 2006; Fisher and Mahajan 2006; Macnaghten et al. 2005). This policy trend calls for and mandates "socio-technical integration" – the incorporation of alternative experts, methods, and perspectives into emerging science and technology programs such as nanotechnology – and goes beyond previous roles for the social sciences and humanities, such as were instituted in the US Human Genome Project (Fisher 2005).

This chapter surveys socio-technical integration (STI) in three prominent political regimes: the United States, the European Union, and the People's Republic of China. These three science policy contexts provide one part of the picture of the state of relations between science and society on a global developmental level. In the case of nanotechnology, the US National Nanotechnology Initiative (NNI) was arguably a key catalyst triggering the global race to harness the envisioned economic and military benefits of nanotechnology, while at the same time, proclaiming an interest in the "responsible development" of nanotechnology. Meanwhile, the EU has attempted to compete not only on a scientific level but also in terms of its ability to ensure "responsible innovation" as a competitive advantage, trying to relegitimize its innovation system in front of European society through policies promoting STI. Finally, the PRC, which claims to have the largest number of publications related to nanotechnology, is paying much less attention than its Western counterparts to socio-technical integration. However, it has lately begun to rethink its science policy from an STI perspective.

To provide more detail with regard to these comparisons, the section on "Socio-technical integration in the United States: the case of nanotechnology" will describe how more recent research policies for nanotechnology in the USA go so far as to redefine research and development in this field as a confluence of technological and societal research. Section on "Socio-technical integration in Europe: European Commission Framework Programmes for R&D" will turn to the European Commission Framework Programmes for R&D, where ELSA (Ethical, Legal and Social Aspects) issues, and publics outside the scientific community, have started being conceived in the last 10 years as dimensions to be integrated into R&D activities themselves. Finally, the last section, "Socio-technical integration in China", will measure the extent to which STI is taking place in China. Even if formal Chinese science and technology policies hardly encourage STI, more and more scholars from both the natural and social sciences and the humanities have embraced the idea of integrating social and ethical concerns at an early stage of science and technology development, particularly in the governance of nanotechnology.

Socio-Technical Integration in the United States: The Case of Nanotechnology[1]

The combination of international competition over the projected economic and technological gains for nanoscale science and engineering – or nanotechnology – and a heightened awareness of the role that societal and ethical concerns can play in the adoption and promotion of innovations led to a hybrid policy for both "rapid" and "responsible" development of nanotechnology. Accordingly, in 2000, the US Congress authored and its President signed into law extraordinary legislative language that mandates (in addition to public engagement and integration) the integration of research on societal concerns with nanotechnology research and development. Specifically, the 21st Century Nanotechnology Research and Development Act (NRDA) of 2003 (Public Law 108–153) requires

> that ethical, legal, environmental, and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity, are considered during the development of nanotechnology.
>
> (US Congress 2003, p. 1924)

At first glance, this language may appear little different from that found in regard to the Human Genome Project's Ethical, Legal and Societal Implications (ELSI) program. The ELSI program constituted what could have been the first "self-critical" US science program (Juengst 1996) and has been adopted and adapted in Europe under the label of "ELSA" (Ethical, Legal and Social Aspects). Despite its innovative character and its role as a model for other forms of social research into science and technology, the ELSI program has been criticized by formal reviews and by scholars for not having interacted sufficiently either with scientific research or science policy processes (Fisher 2005).

The NRDA, however, goes beyond ELSI in listing four distinct means by which the consideration of societal concerns is meant to occur. Here, we focus on the third of the four distinct strategies identified in the law, which largely overlaps with our notion of STI: "insofar as possible, integrating research on societal, ethical, and environmental concerns with nanotechnology research and development, and ensuring that advances in nanotechnology bring about improvements in quality of life for all Americans" (US Congress 2003, p. 1924).

This legal language contains an explicit direction to incorporate, assimilate, and combine social and nanotechnological research. This requirement to integrate research that spans both technological and societal forms of disciplinary expertise – especially insofar as it has the capacity to affect both forms of research – can be thought of as a radical and transformational form of interdisciplinarity: radical because it brings together two disparate forms of scholarship that have been

[1] This section is based heavily on and reproduces portions of Fisher and Mahajan (2006).

differentiated from one another since the ancient formulation of the liberal arts and transformative because of its potential to inform emerging technological developments.

It is informative to consult the official report accompanying the NRDA that was produced by the US House Committee on Science since this helps clarify the objective of the prescribed integration:

> The Committee stresses the importance of integrating research on environmental, societal, and ethical implications with nanotechnology research and development programs to ensure (…) that results of the environmental, societal, and ethical research influences [sic] the direction of ongoing nanotechnology research and development of commercial applications.
>
> (US House Committee on Science 2003, p. 17)

This commentary on the legal language implies that the research and integration activities called for "ought to be able to influence the shape of federally sponsored nanotechnology that finds its way into the public and the natural environment" (Fisher 2005, p. 325).

Evidence that "integration" has been gaining ground in at least some US science policy circles is suggested by a growing trend to incorporate societal considerations into research and development activities, albeit in diverse ways and across a wide variety of contexts. Numerous programs in a variety of science funding and regulatory agencies claim to address societal implications of technological activities, including, but not limited to, the ELSI program, the National Science Foundation's (NSF) "broader impacts" review criterion (Holbrook 2005), Institutional Review Board (IRB) requirements for human subjects research (Sarewitz and Woodhouse 2004), the US Global Change Research "Human Dimensions" program (Janssen et al. 2006), and various President's Council on Bioethics (Briggle 2010). These programs are certainly not analogous, although each claims to supplement technological considerations with societal ones. None, however, goes the distance that the NRDA does in potentially redefining technoscientific research as a collaborative confluence of social and technological research streams.

Thus, as a result of concerns over the public acceptance of nanotechnology and a policy process that signaled a departure from the ELSI model, the NRDA envisioned a new form of R&D in which social, ethical, environmental, and other "nontechnological" concerns and research are explicitly meant to influence the development and direction of new and emerging technologies. But while this radical policy prescription may mark a significant moment in the governance of science and technology in the United States, its implementation is hardly assured. Consider, however, some of the efforts that the NSF has taken and supported in order to realize this policy mandate.

In 2005, the NSF announced several major grants relating to the study of nanotechnology in society (NSF 2005). Included among these was the establishment of two "Centers for Nanotechnology in Society": one at Arizona State University (CNS-ASU) and another at the University of California, Santa Barbara (CNS-UCSB). The CNS-ASU received a $6.2 million award, making it the world's largest center for research, education, and outreach on the societal dimensions of nanotechnology at the time (CNS-ASU 2010). In 2010, the NSF announced that both centers would be renewed for a second 5-year period.

The CNS-ASU pursues a vision of anticipatory governance, which includes the fourfold strategies of foresight, engagement, integration, and their ensembling together in coordinated programs of activity (Barben et al. 2008). The anticipatory governance strategy of integration is largely aimed at increasing reflexivity in the nanotechnology enterprise. The CNS-ASU pursues integration in a number of research and educational forms and venues, the principal one being a coordinated set of more than 20 international "laboratory engagement studies" (Fisher 2007) that span a dozen countries on three continents. This project, called Socio-Technical Integration Research (STIR), is separately funded by the NSF in order to study the extent to which collaborations between social and natural scientists working alongside one another in research laboratories may advance responsible innovation (Fisher 2010; STIR 2009).

The STIR project embeds doctoral students in the humanities and social sciences into laboratories working on a variety of emerging science and technology areas, from nanotechnology and genetics to fuel cells and synthetic biology. These "integration scholars" learn the theory and observe the methods of their natural scientific and engineering counterparts. Importantly, they also introduce an ongoing set of "integration practices" that serve to unpack the social and ethical dimensions of laboratory research in an ongoing, collaborative manner. The integration practices are meant to become embedded in normal laboratory routines and discourses in order to maximize the effects of interdisciplinary collaborations so that these effects can then be studied and assessed in light of the policies and public values that warrant the scientific research in the first place. The social scientists, their methods, and enquiries become part of laboratory research activities during the 12-week period that bounds each lab engagement study.

The types of integrative activities pursued by the CNS-ASU via the STIR project have been found to "trigger changes in laboratory practices – expanding the values and questions considered, and the alternatives that are perceived as viable" (Fisher et al. 2010, p. 1018). For example, as reported in a correspondence in *Nature*,

> reflections on responsible innovation generated novel ideas for antenna structures and nanoparticle synthesis for researchers at ASU's Center for Single Molecule Biophysics. Such developments often advance research and sometimes advance deliberation on public values. For laboratory scientists, thinking and talking about the broader dimensions of their work in an integrated way need not entail a sacrifice in productivity.
>
> (Fisher et al. 2010, p. 1018)

Integration research projects such as the STIR project (Schuurbiers and Fisher 2009) and its cognates at the University of California, Berkeley (Rabinow and Bennett 2009) and at Oakridge National Laboratories (Bjornstad and Wolfe 2011) have different aims and approaches, but generally attempt to conduct innovative, collaborative activities that either assume, question, or demonstrate that "scientific creativity and societal responsiveness can be mutually reinforcing" (Fisher et al. 2010, p. 1018).

Socio-Technical Integration in Europe: European Commission Framework Programmes for R&D

The Framework Programmes (FP) of the European Commission (EC; the executive arm of the European Union) represent the primary instrument for funding scientific and engineering research at the European level. EC research policy has been integrating social and ethical issues with science and engineering at different levels since FP2 (1987–1991). In response to political opposition driven by ethical concerns about a pilot programme on human genome analysis, FP2 implemented an ad hoc expert committee on bioethics in order to address the Ethical, Social and Legal Aspects (ESLA) of research in genomics (Elizalde 1998).

This first ESLA (later ELSA, Ethical, Legal and Social Aspects) research experience in FP2 was followed by regular inclusion of bioethics research in subsequent FPs, where integration became progressively more extensive (i.e., extending across more fields of research). In FP3 (1991–1994), a medical ethics research unit was included inside the subarea of research "Biomedical and Health Research," and inside the "Biotechnology" subarea of research, a series of studies aiming at the assessment of the socioeconomic impacts of biotechnology were supported. In FP4 (1994–1998), ELSA became a common research unit for the three subareas of research (i.e., "Agriculture and Fisheries," "Biotechnologies," and "Biomedicine and Health") included in the research area "Life Sciences and Technologies" (Elizalde 1998).

José Elizalde, the Head of Unit XII.E.5, ELSA-"Life Sciences and Technologies" under FP4, has stated that the integration of ELSA in European research policy resulted in "interdisciplinary projects (…) effectively building bridges between the 'two cultures' of humanities and natural sciences" (Elizalde 1998, p. 13). In the FP4-ELSA website, ELSA research is claimed to promote a "multidisciplinary approach (…) in which a dialogue is established between scientists, doctors, philosophers, theologians, lawyers, social scientists, animal protectionists, consumer and patient groups, industry, etc."[2] However, this interdisciplinarity did not take place at the level of science and engineering research projects, but rather as an autonomous intellectual exercise about science and technology. Therefore, in FP4, ELSA took place, as in previous FPs, as parallel research, instead of being integrated in R&D activities. By "parallel" integration we mean projects studying social and ethical issues that, even if included in, and funded by, science and engineering research areas, function as autonomous, "stand-alone" activities. In FP5 as well, ELSA research was not integrated at the level of core R&D topics (with minor exception), but as parallel "R&D Activities of a Generic Nature" ("Bioethics" subsection) inside the "Quality of Life and Management of Living Resources" research area (i.e., the equivalent to "Life Sciences and Technologies" from FP4).

In the first decade of the 2000s, policy discourse on the integration of ethical, legal, social, and wider cultural issues have become more radical. By "radical" we

[2] http://ec.europa.eu/research/life/elsa/index.html. Accessed March 29, 2011.

mean that social and ethical issues are claimed to be incorporated into science and engineering R&D activities themselves. The Council of the European Union, for instance, stated, concerning the priority research areas in FP6 (2002–2006), that "consideration of the ethical, social, legal and wider cultural aspects of the research to be undertaken and its potential applications (…) will where relevant form a part of the activities under this heading" (The Council of the European Union 2002, p. 7). The same words were reproduced later by the Council of the EU regarding FP7 (2007–2013) (The Council of the European Union 2006).

In addition, ELSA research here is claimed to have become more extensive in comparison to previous FPs, in the sense that this consideration of the socioethical aspects of research is not limited to the realm of the life sciences, but open to any research area in FP6 (The Council of the European Union 2002).

This radicalization of STI by EU policy makers in FP6 needs to be understood in the light of circumstances that provoked a loss of legitimacy of the European science and technology governance system during the 1990s. On the one hand, a series of food crises affected Europe, namely, "mad cow disease" or BSE (bovine spongiform encephalopathy), food and mouth disease in cattle, and dioxin in chickens, which "undermined public confidence in expert-based policy-making" (Commission of the European Communities 2001, p. 19), in the sense that public institutions seemed both unable to control the risks of progress and more aligned with the interests of industry than with the general interest. On the other hand, and fueled in part by these regulatory failures, the European public backlash against agri-food biotechnology from the second half of the 1990s occurred as a reaction by a broad sector of the European publics (environmental groups, politicians, consumer representatives, civil society organizations, farmer organizations, experts, lay public) against what they considered as the uncritical development of a potentially dangerous and unethical technology. In the opinion of these publics, health, environmental, and ethical risks of this technology were being underanalyzed and underregulated in the interest of big corporations (Gaskell 2008). Societal uneasiness with the way in which agri-food biotechnology was being developed stifled institutional and industrial innovation plans, and at the same time, the original regulatory framework became tougher.

The more radical policy perspectives about the integration of socioethical issues in processes of innovation from the last decade are explained in the policy field as responding to an institutional strategy toward the legitimization of the European innovation system. For example, the EC research area "Science in Society" from FP7, which aims "to stimulate the harmonious integration of scientific and technological endeavour and associated research policies into European society" (European Commission 2007, p. 4), subordinates European integration policy to the European Union's strategic goal of becoming "the most competitive and dynamic knowledge-based economy in the world" (European Council 2000, p. 12). This subordination occurs under the assumption that the integration of social and ethical issues in research would facilitate the social uptake of scientific-technological innovations: "For Europe to become the most advanced knowledge society in the world, it is imperative that legitimate societal concerns and needs concerning science and technology development are taken on board" (European Commission 2007, p. 4).

Based on a preliminary analysis of approximately 10 years of European research solicitations, it appears that more radical institutional discourse on the integration of ELSA has been accompanied by an actual transformation of integration at the level of research policy practices. Additionally, we can cite instances of policy discourse on "public" integration. Two examples are Regulation (EC) No. 2321/2002 concerning the rules for participation in FP6, where it is stated that "activities under the Sixth Framework Programme should (…) improve information for, and dialogue with, society" (The European Parliament and the Council of the European Union 2002, p. 24), and Zoran Stančič's (former Deputy Director-General of the European Commission Directorate General for Research) claim, in the middle of the transition FP6-FP7, that "more must be done (…) to find ways of actively engaging with civil society, stakeholder groups and the public at large in the preparation and execution of research" (Stančič 2007, p. 1). In this sense, it is also significant that the "readiness and capacity to engage with actors beyond the research community and with the public as a whole, to help spread awareness and knowledge and to explore the wider societal implications of the proposed work" (The European Parliament and the Council of the European Union 2002, p. 28) was established as a common evaluation criterion of research proposals under every research area in FP6.

A further step in this analysis would be to determine the extent to which these apparently evolved characteristics of STI at the policy level of research solicitations are affecting the way in which scientific and engineering research is conducted in Europe, an issue that has begun to be addressed within the EC (e.g., Braithwaite et al. 2007). However, this is a topic that exceeds the scope of this chapter.

Socio-Technical Integration in China

As a developing country, economic development is China's current priority. It is rather uncritically assumed that science and technology always play major roles in promoting economic growth. Consequently, China's research policies mainly focus on the development of science and technology per se, with little attention to STI.

However, there are some governmental regulations in the People's Republic of China concerning ethical or social aspects of science and technology, especially in the field of medicine and biotechnology. In the newly revised Law on Progress of Science and Technology, it is clearly stipulated that "The nation forbids any research and development activity of science and technology which harms national security, social public good, human health or violates morality and ethics" (National People's Congress of PRC 2008). This is the first time that a Chinese national law established a forbidden zone for scientific-technological activities.

At the same time, the Chinese scientific community has become more aware of the ethical dimension of scientific research. On February 26, 2007, the Chinese Academy of Sciences (CAS) issued two reports addressing this issue: "Declaration on the Idea of Science" (CAS 2007a) and "Suggestions for Improving the Norm Construction of Scientific Research Conduct" (CAS 2007b).

The declaration admits that while science and technology produce enormous spiritual and material wealth, they can also create side effects and challenge established social ethics. This means that scientists need to conduct their activities in a socially responsible way. Scientists should try consciously to avoid any negative side effects of their research activities and be responsible for assessing these side effects. In addition, they should provide adequate warnings to society and change or even stop their research once malpractice or risk is detected (CAS 2007a).

The suggestions set forth concrete requirements in order to improve the academic environment and also to identify and treat scientific misconduct. To implement these requirements, CAS and its affiliate organizations set up a commission for scientific research morality. With these two documents and other relative instructions or codes, CAS has established a relatively comprehensive normative system (CAS 2007b).

In addition to the normative initiatives taken by the government and the primary research community, socioethical dimensions of science and technology are being addressed in higher education, where future scientists and engineers are introduced to and study the social aspects of their activities. In higher education, Science, Technology, and Society (STS) institutes and centers have been established in many leading Chinese universities. Indeed, every Chinese university has an STS teaching section. An introductory course called "Dialectics of Nature" is compulsory for all masters students majoring in the natural sciences, engineering, agriculture, and medicine (Cao 1995). All Ph.D. candidates in those majors have to attend a similar course known as "Modern Revolution of Science and Technology and Marxism." The two courses function as both an ideological and a liberal education for future Chinese scientists, engineers, and physicians, providing them knowledge of basic views on nature, methodology of science and technology, and STS.

Socio-Technical Integration at the Academic Level: The Promising Case of Nanotechnology

There are few formal policies on socio-technical integration at the governmental level. However, more and more Chinese scholars from both the natural and the social sciences and humanities have been realizing on their own the importance of integrating social and ethical concerns at an early stage of science and technology development. This academic trend for integration is evident in the governance of nanotechnology.

Programs and initiatives on nanotechnology in China were started in the 1980s. During the past 20 years, China's nanoscience and nanotechnology research has developed rapidly. To date, more than 50 universities, 20 institutes, 600 companies, and 5,000 researchers have become engaged in nanoscientific research and nanotechnological development (Liu 2009). In 2007, China ranked number one in nanotechnology papers published in the Science Citation Index worldwide

(Zhao 2010). At the same time, the commercialization of nanotechnology is gradually increasing. Although still in its infancy, around 1,000 enterprises are involved in nanotechnology in China (Zhao et al. 2008).

With the rapid development of nanotechnology application fields, the issue of nanotechnology safety has given rise to serious public concern. Learning from European and American experience, leading scientists from the CAS Institute of High Energy Physics (IHEP) suggested in 2001 that the environmental and toxicological impacts of manufactured nanomaterials should be studied (Zhao and Bai 2005). In 2003, the Laboratory for Bio-Environmental Health Sciences of Nanoscale Materials was established at IHEP.

These appeals by high-level scientists quickly drew government attention. In 2004, the highest-level scientific meeting organized by the Chinese government, held in Beijing Fragrant Hill, was about "Nanosafety: Biological, Environmental and Toxicological Effects of Nanoscale Materials/Particles." Currently, more than 30 research organizations in China have initiated research activities studying the toxicological and environmental effects of nanotechnology (Zhao et al. 2008).

All of this demonstrates that safety research on nanotechnology in China has become an increasingly important topic. Yet the concept of "nanosafety" relates not only to technical risk but also to societal risk. In this sense, China lags behind Western countries. This situation began to change in 2008, after the second National Bioethics Conference, as nanotechnology gradually attracted the attention of Chinese social scientists and humanities scholars.

So far, among the efforts made in the STI of nanotechnology development, the workshop on "Nanoscience and Nanotechnology and Ethics" held in 2009 by the subcommittee on Ethics of Science, Technology and Engineering of the Chinese Society for Dialectics of Nature, and the Chinese National Center for Nanoscience and Technology, could be called a milestone. Experts from the natural sciences and the humanities and social sciences discussed together the possible ethical and social issues of nanotechnology. In the end, they reached a consensus that the development of nanotechnology requires the engagement of philosophy and ethics. Even if this interaction between nanoscientists and scholars from the humanities and social sciences does not yet occur at the R&D level, this cross-disciplinary dialogue is a good starting point for deeper STI in future R&D activities in China.

Public Understanding of Science and Technology, and Public Engagement

The relationship between science and the public in China is mostly framed in terms of the deficit model: the public needs to be scientifically enlightened. Experts and bureaucrats are the only actors who make decisions on the development of science and technology.

Nevertheless, along with other aspects of social progress taking place in China, a new trend has been emerging that emphasizes public engagement in the development of science and technology. For example, a public activity on genetically modified foods (GMFs) was held in the Western District of Beijing in November–December 2008. This event was jointly initiated by the Center for Strategic Studies of CAS, Center for Ethics of Science and Technology of CAS, Committee of Science and Technology of Western District of Beijing, and Office of Desheng Subdistrict. Drawing on the model of Danish consensus conferences, it was the first experience of such a public engagement activity in mainland China. The theme of this activity was "Science in Community." A selection of 20 volunteers was made according to gender, age, education, and career criteria. In addition, four experts on STS and science communication participated.

This activity consisted of one preparatory meeting and two formal meetings. During these meetings, citizen volunteers were first provided with basic information about GMFs, ELSI issues, and governance problems. Then, experts and volunteers exchanged opinions and had a discussion on the risks and uncertainties surrounding GMFs. Role play was introduced to improve communication. It was noticed that these volunteers were a little bit uneasy at the beginning regarding critical thinking about science and technology, as they were accustomed to consider science and technology as intrinsically good and absolutely powerful. But soon volunteers began to understand that social, economic, political, and cultural factors are constitutive of any technological product (Li 2009).

This participatory experience was only a first-time experiment for Chinese social researchers. Nevertheless, it was a promising beginning, an attempt to import some European and North American approaches into the Chinese context. All in all, this trial indicated that there is great potential for actively engaging Chinese citizens in science and technology-related issues.

Conclusion

This chapter has surveyed STI practices in the research policy systems of three prominent political contexts: the United States, the European Union, and the People's Republic of China. The analysis points, first, toward some pronounced differences between both the USA and the EU, on the one hand, and China, on the other, regarding STI. In both the USA and the EU, R&D has been redesigned during the early 2000s in terms of a policy demand for incorporating social and ethical considerations in ongoing science and engineering research practices, while in China research policies pay little attention to STI.

In the USA, there is an explicit legal demand to integrate social and technological research streams in nanotechnology R&D activities. In this sense, STI as formulated in the context of nanotechnology research goes beyond former experiences such as the ELSI program, which became institutionalized as one of the components of the US Human Genome Project but functioned primarily as a "stand alone" exercise, not connected to R&D processes.

In the EU, research STI policy, as formulated in the Framework Programmes for R&D, evolved in the early 2000s into more radical forms of integration. This means that socioethical and legal issues, previously pursued as "stand alone" or parallel activities, are promoted as dimensions to be incorporated into science and engineering research practices themselves, in ways similar to that of US nanotechnology research. In the EU particularly, STI is conceived as part of EU's effort for legitimizing its science and technology governance system. This has been questioned most prominently beginning in the 1990s by broad sectors of European publics, which argue that science and technology developments should integrate more seriously the interests and concerns of society as a whole.

Finally, in China, research and development policies are not promoting this kind of strong STI. Due to China's special historical context, economic development is the basic priority, and science and technology are promoted as playing major roles in fostering economic growth. Critical thinking about the possible negative effects of science and technology remains rare, even if some ethical regulations for science and technology have been established both by the government and researchers themselves. Nevertheless, scholars from both natural and social science and humanities have embraced the idea of integrating social and ethical concerns at an early stage of science and technology development. Furthermore, recent experiences of public dialogue on scientific issues may point to the development of more integrated research in China's future.

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Chapter 18
Inheritance Ethics in Engineering Development: Comparison Between Shenyang and Ruhr on Industrial Heritage Conservation

Jian Wang and Jia Chen

Abstract This chapter develops an ethical approach to thinking about obligations toward the preservation of industrial heritage. Industrial heritage is an aspect of cultural heritage dealing specifically with the buildings and artifacts of industry which are inherited from past generations, maintained in the present, and bestowed for the benefit of future generations. We also refer to these broadly as "inheritance ethics." As a central case study, we compare the approaches to the preservation of industrial heritage between the Ruhr district of western Germany and the Shenyang urban region of northeast China. We discuss how different engineering decision-making mechanisms lead to different ethical choices about heritage and inheritance. The main example of Shenyang city will demonstrate, similar to other cities in China, that architectural and older industrial ruins were considered unsightly and polluted. As such, these sites have often been destroyed, thus erasing the material, architectural, and industrial heritage of previous generations. While many sites of ancient cultural heritage are protected in China, the question goes unanswered as to whether we have the right to destroy the historical imprint left by our more recent industrial lineage. Further, we inquire as to whether China can realize a development ethics that considers both the needs of future generations as well as the heritage left by previous generations.

Keywords Engineering • Inheritance ethics • Industrial heritage • Labor

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Introduction

Traditional engineering in China was not so much a process of applying technological knowledge in a straightforward manner as much as it was a holistic process from conception to production by methods of trial and error. Within these traditional practices, there is a definitive process of checking engineering outcomes at any step of the trial-and-error process and feeding these results back into ongoing developments. In other words, traditional engineering was not a value-free process for optimizing solutions; rather, it was more of an ongoing value-laden decision-making process with significant ethical implications (Schinzinger and Martin 2000). Research on engineering ethics has mainly focused on two aspects thus far. First, during the early stage of engineering ethics, the main focus was on professional ethics, such as the relationships between technological engineers, entrepreneurs, and the workplace (Yu Mou-chang 2000). The second main consideration in the development of engineering ethics was the rethinking of relationships between people and the environment. American biologist Robert L. Sinsheimer argues that modern science and technology were built with two foundations, one of them was the belief in "the restorability of nature" and that even nature was "merciful." There was a "belief that our scientific exploration and technological adventure will not replace some of our key elements to protect the environment, thus, it will not damage the ecological balance," and "that nature will not lightly set a trap for the species" (Mitcham 1999). But over recent decades, this belief has come under more and more scrutiny.

As a result, certain groups within engineering began to think more critically about the issues posed by ecological ethics. In 1976, the American Society of Civil Engineers (ASCE) first defined an ecological dimension to engineering ethics by asserting that engineers "should take the responsibility of improving quality of environment and life." In 1983, the statement was revised to "engineers should provide services in this way, which is, for protecting the interests of present and future generations, saving the world's resources, cherishing the natural and artificial environment." In 1996, the statement was further refined to say that engineers "should put public safety, health and welfare at primacy, carry out their professional responsibilities meanwhile comply with the principles of sustainable development." On the one hand, sustainable development was articulated in a way that meets society's current needs and sustains its development by continuing economic and technical activities. On the other hand, economic and technical activities must be conducted within certain ecological limits that assure no harm is done to the "natural ability to absorb the impact of human activities" and that no harm is posed "on future generations to meet their capacity needs and aspirations."

Reflecting the protection of and respect for natural systems, as well as the consideration of the needs of future generations, we conclude that environmental responsibility is an important consideration for all engineering activities. But when we reflect on the implementation of environmental ethics within engineering activities, there are areas worthy of further consideration and research. For example, contemporary engineering activities are inherently different from those of ancient activities, in that most ancient engineering activities were developed to work within natural ecological systems, while most contemporary engineering activities are technological and nonnatural in character. So, by emphasizing the protection of natural systems, does this provide a precedent for the protection of some aspects of artificial systems? That is, if the protection of natural and ecological systems reflects the ethical relationship between contemporary and future generations, which we can refer to as "development ethics," then, the protection of artificial (human-built) systems reflects the ethical relationship between contemporary and previous generations, which we will call "inheritance ethics."

Concept and Essence of "Inheritance Ethics"

Concept of Inheritance Ethics

In Western philosophical tradition, the word ethics is derived from the Greek "ethos," meaning *custom*, *habit*, *temperament*, *and personality*. In this sense, inheritance ethics pertains to the inheritance of customs and habits from previous generations. Narrowly defined, inheritance refers to the passing on of property from one generation to the next, which is customarily accompanied by a formulation of private ownership. It is because of the concept and custom of private ownership that it is both legal and perceived as the natural course of things to inherit personal property after the death of family members. Thus, inheritance law is the result of the legalization of the custom of inheritance. Broadly speaking, inheritance customs include the inheritance of both material and intangible cultural products in human history, such as the protection of our cultural heritage. Further, many cultures throughout the world exhibit some form of a cultural heritage protection law. In this chapter, we adopt the custom of inheritance in a practical sense. As such, we define the concept of inheritance ethics as a kind of ethical relationship formed through the processes of inheriting both material and intangible cultural products created by people throughout history along with a series of formal and informal regulations for achieving this transition between past and present.

Inheritance ethics not only refers to the obligations of those who inherit but also occurs between and among those who inherit and the objects that are inherited. In other words, the relationship includes both the ethics among contemporary people and between previous generations and contemporary generations. Unlike general ethical relationships between living individuals, this ethical relationship is not a direct obligation between living human beings, but rather poses an indirect obligation where inherited artifacts act as intermediaries between peoples' past and present. Thus, an ethical relationship is developed in and by the attitudes and behaviors in how contemporary generations treat the artifacts created by previous generations. For example, because of the difference in political, economic, and cultural factors, different regions and peoples have different attitudes about their own material and intangible heritage.

Essence of Inheritance Ethics

Ethical relationships entail a social relationship that is evaluated based on preferences of good and bad, formed as part of the social life of people. Since artifacts are the medium of inheritance relationships, they reflect the ethical aspects of human nature. As we know, artifacts are the result of human labor; they are the materialized form of human labor. Labor not only shapes subjectivity, the experience and consciousness of labor are embodied in the form of tools as socially constructed objects. In the process of labor, subjects become both materialized and objectified, that is, subjects themselves are the objects of labor.

In this case, the artifacts inherited by contemporary generations are the substance by which previous generations constructed themselves through the process of labor. That a contemporary generation protects and respects artifacts demonstrates respect for the material culture of previous generations as well as a respect of previous generations' labor. In terms of value, the artifacts from different periods can be compared in terms of value relative to contemporary contexts. A primary reason for this is because artifacts solidify undifferentiated human labor. Besides, the older the history of an artifact in continuous use, the more value there is in the labor. In this way, inheritance ethics is based on artifacts coupled with human labor; respect of artifacts is a respect of the work of previous generations. Simply speaking, the essence of inheritance ethics is respect of past human work; it is the inheritance of human work and the result of human work.

Two Dimensions of Engineering Ethics

From the consideration of labor, the essence of engineering is a form of humans at work. As such, engineering ethics should also embody respect for human labor, with two orientations. One orientation is to point to the future, and one is to point towards the past. Sustainable development points toward the future in engineering ethics. This demonstrates respect for future generations by assuring them of the opportunity of work. One reason that contemporary generations ought to take responsibility for protecting ecological systems is that we are obligated to assure our future generations have more labor resources rather than less. In essence, labor in environmental ethics is the future generations' capacity to enjoy the same rights of labor, which is a form of development ethics. However, as we have already mentioned, modern engineering has not only shaped natural systems but also artificial systems, that is, the artifacts created by humans throughout history. Thus, in addition to considering the issue of labor rights in the engineering activities of future generations, there is a symmetrical need to consider and evaluate the labor of previous generations, that is, how a contemporary generation handles the preservation of artifacts created by previous generations. As such, inheritance ethics is a development ethics that looks toward the past.

Industrial Heritage Protection: Implementation of Inheritance Ethics in Engineering

Industrial Heritage: The General Intermediary of Inheritance Ethics in Engineering

Inheritance ethics is manifested in the artifacts created by people as an intermediary in social relations. Although there are various kinds of artifacts in engineering activities, we can categorize the artifacts into major types according to the way human civilizations have developed. Types before industrialization are the artifacts produced by agricultural civilizations and animal cultures; the other type is the artifacts produced by industrial civilization.

Agricultural civilizations have a long history, and many artifacts created during these times have been recognized as important historic relics. These include, in China, the Dujiang Weirs, the Great Wall, and old Beijing City. The protection of these historic relics is not only an ethical responsibility; it also carries legal responsibilities both nationally and globally. In this sense, protection of artifacts created by agricultural civilization and animal culture are more akin to historic-relics-protection legal liability rather than the intermediary of inheritance ethics. As classified above, however, it is urgent to resolve the problem of what engineering should do with industrial heritage, that is, the artifacts created by industrial civilizations. Since industrial artifacts were generated within or after the industrial revolution and thus closer to contemporary contexts, the value of industrial relics is not perceived as being of historic value given the perceptions of the negative and polluting effects of industrial civilization.

The Nizhny Tagil Charter for Industrial Heritage, published by TICCIT in 2003, defines industrial heritage as

> Industrial heritage consists of the remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education.
>
> The Nizhny Tagil Charter for Industrial Heritage (TICCIH 2003)

Since the origin of industrial civilization, every domain of human society has been marked by the rise of industrial manufacturing. At this point, human society cannot both sustain and continue to develop without some form of industrial manufacturing. Engineering activity launched the artificial nature which is composed of massive industrial heritage. Industrial heritage has become the most general intermediary to inheritance ethics in relation to engineering.

Industrial Heritage Protection: The Institutional Arrangement of the Ethics of Inheritance in Engineering

The guideline of inheritance ethics in engineering attempts to make the "ought" of an engineering activity (the cognition of the "good") come to fruition (the real-world choice and practices of an engineering activity). The "ought" principle embodies the cognition of value and the moral assessment of an engineering activity, which is formulated as a kind of ethical norm of respect for achievements created by ancestors. As for real-world practices, respect for past achievements includes all activities motivated by the needs of human beings which modify and utilize nature. However, knowing something "ought" to be done does not necessarily mean knowing how to do the practice, as institutional arrangements need to come into play as well.

The essence of inheritance ethics is to show respect for the endeavors of our ancestors, which is the appropriate spirit needed for movement toward the protection of industrial heritage. As a further illustration of industrial heritage in China, the situation in the northeastern (Dongbei) area of China provides a good example. The northeastern area is one of the most important parts in China's development of modern industries. Furthermore, this region is also a crucial component of the establishment of New China.[1] Most of the significant infrastructures such as factories, production systems, machines, buildings, warehouses, railway stations, and workers' residential areas all demonstrate the achievements that people living during that period accomplished, as well as their beliefs and aspirations concentrated within this area.

We attempt to show our basic respect for the achievements of our ancestors in all engineering activities, but the reality is that an engineer performs fundamentally as a rational and self-interested *homo economicus* instead of a *homo ethicus*. This means that the economic reality of the situation always puts us in the middle of a dilemma and forces us to sacrifice the achievements of our forefathers, showing some sort of disrespect toward the ancestors and a disobedience to the ethical norms of inheritance. China's industrialization presents just such a situation. To accelerate the growth of net GDP and to realize the adjustments and upgrades of the industrial structure, many cities began to develop land transformation projects on a large scale, which led to the deconstruction of preindustrial heritage sites. Nowadays, it is hard to trace back material culture of these past eras.

[1] "New China" here means People's Republic of China (PRC) which was founded in 1949.

Actually, practicing an ethics of inheritance by only keeping simple ethical judgments in mind and learning that it is good to respect our ancestors' productivity is not enough: the individuals involved must set up institutional arrangements to guarantee the implementation of the norms in real-world practice. To exercise the ethics of inheritance, protection of industrial heritage needs to be secured by a series of detailed institutional arrangements, such as the identification of industrial heritage and industrial heritage protection regulations.

Context Dependency of Inheritance Ethics Implementation in Engineering: A Comparison of Industrial Heritage Protection Between Shenyang, China, and the Ruhr District, Germany

Engineering ethics is a practical ethics. Ethical practice in engineering is a comprehensive, creative ethics, which combines universal principles and existing special situations, facts, and values, together with ends and means to make choices across the range of possibilities (Zhu-Baowei 2006). As an important part of engineering ethics, the implementation process, methods, and results of inheritance ethics are context dependent. We can get some insight through the comparison of approaches to industrial heritage protection between Shenyang, China, and Germany's Ruhr district.

Industrial Heritage Protection: The Ethical Dilemma in the Reconstruction Process of Two Traditional Industrial Areas

The Ruhr district, or Ruhr region, is an urban area in North Rhine-Westphalia, Germany. With an area of 4,435 km^2 and a population of some 7.3 million, 9% of the whole nation, the Ruhr district is the largest urban agglomeration in Germany. The Ruhr district was regarded as one of the most important industrial regions in Germany and is also one of the most important heavy industrial areas in the world. Industry from the Ruhr district was used as the manufacturing base in support of Germany's efforts during the two World Wars. After the Second World War, the region also played a pivotal role in the recovery of businesses and was the springboard for Germany's economic rise. The share of industrial output in the Ruhr district was 40% of the value of the output of the entire country. The prominent industrial characteristics in the Ruhr region are mainly heavy industry such as coal, steel, chemical, and machine manufacturing. These formed the foundation for regional industrial syntheses with complex bureaucratic structures, close internal relations, and spatially concentrated industry. The Ruhr first developed as an urban region during the Industrial Revolution because of its abundant coal-mining industry.

With the multipurpose use of coal, it gradually developed coking plants, electricity generation, coal chemistry, etc. Thus, steel and industrial chemistry developed accordingly, based on these material factors. The Ruhr further established its machine manufacturing industry, especially heavy machinery, nitrogen fertilizer industry, and building materials industry (Ren-Baoping 2007).

After a century of prosperity and development, from the beginning of industrialization through the late 1950s, the Ruhr district encountered a “coal crisis” and a “steel crisis” which quickly led to a decline in the regional economy. Due to significant increases in world coal production, coupled with the widespread use of oil and natural gas, the Ruhr was forced to reduce the mining of coal. By the mid-1970s, during the global economic crisis, the trend of deindustrialization in the Ruhr became quite clear. Thus, the Ruhr district faced a pressing need to transform its traditional industrial structure. For example, in 1957, the Ruhr had 140 coal-mining bases, but only seven of them remain open today, and in 1955, there were 81 steel-manufacturing furnaces, now only seven remain. By the late 1980s, the Ruhr was facing serious unemployment problems; as data demonstrate, in 1987, the Ruhr had its highest unemployment rate at 15.1%, well above the national average unemployment rate of 8.1% at the time (Ruhrgebiet 2001). The Ruhr’s Emscher region, which had the highest per capita gross national product of Germany in the 1950s, then became the region with the highest unemployment rates and greatest social problems for all of western Germany.

Returning to China, we choose Shenyang which has similar conditions to the Ruhr to examine how China progressed in modern time. Shenyang is an important industrial city in China, which has a special status in China’s industrial development. Shenyang’s “Tiexi” District, an important industrial area, is also referred to as the “Eastern Ruhr.” The urban region of Shenyang has rich mineral resources and geographical advantages and formed a strong industrial base during the Manchukuo period (1931–1945). After the foundation of the People’s Republic of China (1949), the state invested significant capital in Shenyang into establishing it as the primary equipment manufacturing industrial base. In the first “Five-Year Plan” period (1949–1954), there were nearly 1,500 construction projects and more than 50 state-key projects. During the decades of large-scale industrial construction in Shenyang, hundreds of “China First” projects were developed, a large number of “labor models” emerged, and Shenyang was referred to as the “eldest son” of the Republic’s industry, where there are rich industrial heritages throughout the Shenyang region. Yet, with the change of economic systems and state-owned enterprises and the worldwide upgrading of industrial infrastructure, Shenyang is also facing a similar problem to the Ruhr of needing to transform its old industrial areas.

Although renovation engineering happened at different times in these two industrial areas, they both contain old industrial zones and large renovation projects took place in preserving the artifacts and heritage of their respective industrial cultures. So, both regions are faced with the ethical dilemma as to how to approach protecting their industrial heritage. If industrial heritage is fully retained to show the overall work history of a previous generation, reflecting respect to traditional industrial workers, it will hurt the immediate interests of contemporary people who need new space to develop new industries and create new employment opportunities. However, if there is a disregard for the labor of previous generations and industrial heritage is fully removed, the precious history of human labor will be lost. Further, if the opportunity to be able to restore this history is lost, it will be a significant loss to contemporary and future generations' capacity to fully comprehend its industrial heritage.

Differences in Resolving Ethical Dilemmas Between Different Engineering Contexts

Both the Ruhr and Shenyang traditional industrial areas have suffered ethical dilemmas in transforming their old industrial areas, but due to their different situations, they have come up with different solutions. Here, we discuss how different engineering decision-making mechanisms lead to different ethical selections about heritage and inheritance.

Different engineering decision-making mechanisms will lead to different ethical selections around issues of inheritance. By comparing the renovation projects in Shenyang and in the Ruhr, we believe that, regardless of the location, there are four possible ethical choices to be made in protecting industrial heritages: (1) eliminate and destroy completely, (2) reconstruct after demolition, (3) recycle, and (4) develop comprehensively (Li Leilei 2002).[2] However, due to the different decision-making mechanisms, the outcomes of the two industrial areas are different.

Comprehensively speaking, there was a gradual process towards recognizing the importance of industrial heritage and in becoming more proactive toward this position in the industrial updating and transformation of the Ruhr. In this engineering activity, governments, intellectuals, and local residents became stakeholders in the decision-making process. Different from other engineering activities, engineering activities in the protection of the Ruhr's industrial heritage not only pay attention to principles such as responsibility, utility, fairness, and ecological protection but also apply inheritance ethics in decision making as an important aspect of the consultation in the decision-making process:

- *Theory research and rejection based on practice.* The concept of industrial heritage came originally from industrial archeology, which came to the field of mainstream archeology during the second half of the twentieth century. Practitioners from backgrounds as diverse as public and private museums, railway preservation societies or canal restoration groups, and academics from a variety of disciplines, as well as professional archaeologists and architects, had widely debated across the scope of the subject. First, local governments and citizens regarded these relics as symbolic of the decline of the industry—as dirty and ugly—and should

[2] In practice, leaving industrial sites exactly as they are is also an option. Here, we just make an additional choice on how we could deal with industrial heritage, but not an opposition.

be destroyed and dismantled. For example, in 1968, the first project in the Ruhr proposed by North Rhine-Westphalia was called the "Ruhr Development Program" and focused on the cleanup and rectification of the mine areas to attract new industry and provide new development opportunities.

- *Spontaneous protection initiated by scholars with the participation of stakeholders.* With deepening research in the theory of industrial archeology, large changes in how to treat their industrial heritage happened among the Western countries. For example, Zollverein II, located in Dortmund, was to be dismantled. However, architects became captivated by the early industrial architectural style at the site. Further, Zollverein II was the first mining operation in the world that used electrical pumps, which could thus be regarded as a site of world technological heritage. Architects organized a photographic exhibition for the mine, the local media also spared no effort in reporting on this, and, for the first time, the general public became concerned with the industrial buildings around them. This was also the first time that a social movement of concerned citizens drove local government to consider their sites of industrial heritage from a more holistic view (Hajdu and Bochao 2006).
- Combining the traditional utilitarian programming model, which emphasizes the absolute authority of the government, and the "up-stream" model considers the needs of local stakeholders. Consider the International Building Exhibition Emscher Park (IBA) project at Ruhr for instance. The IBA project from 1989 to 1999 planned to construct a landscape park along the Emscher River 70 km long and with an area of 320 km^2. Under the guidance and leadership of Prof. Karl Ganser, IBA Emscher worked out and finished more than 120 projects along the Emscher River with the cooperation of local government, country, and EU.

Let us consider the participation mechanism of IBA. IBA is a dual-nature institution with the national and local governmental powers. Ideas from nongovernmental organizations should pass through professional assessment via expert council, which then becomes the official project with authorization by the government. Within this process, there is cooperation between governmental and nongovernmental organizations, from formulation to implementation, throughout the entire planning process (Hassenpflug 2005). The IBA project actually provides a platform based on a regional development perspective to enable people to share extensive discussions on the planning, communication and consultation processes, and a procedure for balancing various interests and aspirations in case of conflict, allowing an acceptable consensus to be reached by all parties. From another side, the planning participants should include members from government, local society in private enterprise, and nongovernmental organizations. Therefore, the IBA project acted as an agent and trader in balancing the interests of different groups through the development of a mutually beneficial goal.

Shenyang has remained in the planned economic system of the PRC for much of its history. After the economic reforms of the 1980s, the market gradually became the main mechanism of economic operation, but because the market mechanism is not quite mature, the government still takes a leading role in decision making, which is further hindered by a lack of public participation in the decision-making processes that are inclusive of stakeholders. From 2002 to 2007, under the direct leadership of the provincial government, it took less than 5 years to complete the demolition of the entire industrial zone slated for reconstruction. In a survey, we learned that a number of older workers of bankrupt enterprises wanted to remain in the factory where they had worked for decades. There were also some well-known scholars, such as When Yu, professor of Landscape Institute, Peking University, who were strongly opposed to blowing up the century-old Shenyang Smelting Factory. But these did not change the choices made about reconstruction after demolition because there was no public participation in the decision-making procedures. In less than 5 years, 258 enterprises were relocated to open land measuring 8.56 km^2, a large number of industrial buildings from the Manchukuo era, the liberation war, and the first "Five-Year Plan" period were demolished. After this mass destruction, the government began to reflect more on attitude toward continuing its industrial heritage and then began to rebuild after the destruction. In 2007, a village courtyard (seven housing buildings) of Soviet-style dormitories built during the first "Five-Year Plan" period and the Shenyang Foundry built during the second "Five-Year Plan" period were transformed and utilized protectively. They were respectively rebuilt as a living museum to industrial workers and as a foundry museum showing the complete aspects of traditional workers' lives. Nevertheless, the new city of Shenyang, with its commercial buildings, has completely lost the former "Eastern Ruhr" style of it industrial heritage. Shenyang has lost its unique cultural symbols forever.

Conclusions

From the perspective of labor, engineering ethics should be discussed along two dimensions: with respect to the labor rights of future generations and with respect for the achievements of the labor of previous generations. The former has generated widespread attention but the latter still has an unformed status. Paying attention to the latter and learning to respect the achievements of both the recent and the distant past, inheritance ethics will help to better guide ongoing engineering activities and protect China's industrial heritage.

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Chapter 19
Dam Construction Ethics in China

Zhihui Zhang

Abstract Dam Construction in China has produced significant societal benefits. But in recent years, large dam construction has been strongly criticized both nationally and abroad. This chapter argues that the criteria for evaluating the construction of dams should include expanded perspectives from engineering ethics. It also briefly analyzes the ethical problems associated with large dam construction in China and points out divergent ethical assessments within the Chinese experience. Finally, the chapter argues that while there are certain ethical standards that universally apply in engineering, American as well as other foreign standards are not always appropriate in the Chinese context. When it comes to dam construction, China needs to establish its own ethical standards and engineering practices.

Keywords Engineering ethics • Dam construction • Engineering principles

Introduction: Dam Construction: To Be or Not to Be?

China benefits greatly from the construction of modern dams. They provide abundant and inexpensive water for public use as well as for agricultural irrigation and industrial or commercial application. Dams further aid in the management of floods and droughts. However, in recent years, a number of controversies have developed related to local economic and societal issues.

By the end of the twentieth century, there had developed intensive criticism of European and American dams and hydropower plants built during earlier parts of the century. As support for environmental and ecological protection grew, these

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concerns spread to China. As a result, China has witnessed its own rising ecological consciousness early in the twenty-first century. Arguments about merits and demerits of the Three Gorges and the protection of Dujiang Weir versus the development of the Nu River and Tiger Leaping Gorge hydropower became fierce. Advocates from the academic community as well as politicians, entrepreneurs, engineers, the media, environmental organizations, and the public presented views on whether or not various dams should be constructed. Arguments were not confined to scientific or engineering issues, but included many different ethical and cultural perspectives. To some extent, disapproval of the construction of dams affected hydropower and hydroelectricity policy in China, making the prospect of further dam construction uncertain.

Should China continue dam construction? Criteria for the building of dams are not only scientific and technical, but reference a complex set of environmental, ecological, economic, and social factors, all of which should be combined in a comprehensive evaluation of any proposed dam project.

Ethical Issues with Large Dams in China

There are a number of important issues related to dam construction in China today. These may be summarized in terms of four tensions:

1. Public expectations versus professional ethics among engineers. Engineers are often assumed to shoulder a higher degree of ethical responsibility than others involved in large-scale projects. However, an examination of the guidelines of the Chinese Hydraulic Engineering Society (CHES) and the construction regulations of Chinese National Committee on Large Dams (CHINCOLD) reveals no written professional code of ethics for hydraulic or dam engineers.

On the one hand, engineering is recognized as a professional discipline in which civil engineers focus on designing dams that control floods, generate power, irrigate farm land, and do not collapse. Their responsibility is to “do right” what they have been asked to do rather than to consider “what is the right thing to do.” Dam engineers seldom think their job includes considering ecological impacts, population relocation, or other factors. For example, during the development of hydropower in southwestern China, engineers focus almost exclusively on technological issues and ignore environmental impacts. For example, the Longtan Dam in Guangxi province, which was designed to maintain a normal reservoir water level of 378 m and a total capacity of 16.2 billion cubic meters, required extra modeling and hydraulic tests. After the project was finished, engineers took pride in how the project contributed to flood control, power generation, and economic efficiency. Their political propaganda concerning environmental benefits was limited to noting how it did not add to carbon dioxide emissions while those long-term geological, hydrological, and ecological effects which concerned the public were ignored.

On the other hand, in a feasibility study for Nu River hydropower development, it appears that engineers allowed special interests to influence their recommendations. Such behavior undermines the public trust in professional expertise.

2. Privileged government interests versus engineers. Large dam construction is an active process that involves society as a whole. “In addition to scientists and engineers, those involved include investors, policy makers, employees, managers, inspection experts, as well as end-users” (Zhu Baowei 2006). Different groups have different interests. This makes it crucial that others share access to the same knowledge base as engineers. Only when all parties are well–informed and are given opportunities to communicate their concerns can a holistic strategy for some particular dam project become possible. When some groups have more access to knowledge than others, this can distort the dam design and construction process.

In China, large dam construction is driven by strong government support and various pro-dam groups. China has long suffered from flooding, which causes water management to be a core concern of national development and stability. China’s government, which functions as both policy maker and dam builder, thus manifests a fundamental commitment to large-scale hydro projects. Since dam construction requires extended construction periods (typically 5–10 years) and massive social welfare efforts to relocate affected immigrants, it requires huge amounts of financial support from both central and local governments. Thus, it is reasonable that the government should have a final say in whether or not some particular dam construction takes place.

Since the national reforms initiated under Deng Xiaoping, China has shifted from a planned economy to a market economy. This has made the role of government at times unclear, allowing some problematic issues to be resolved by individuals but not others. This ambivalence is reflected in dam construction. For example, while large dam projects are approved by the National Development and Reform Commission, and small- to medium-sized reservoirs by the Ministry of Water Resources, the central government seeks to control the overall strategy for dam construction. However, during the hydropower boom in southwest China, large dam projects only needed to be approved by a provincial Development and Reform Commission.

At times, engineering decision-making can also be caught in a tug-of-war between the central, provincial, and municipal governments. One example was a dispute between the Shaanxi and Henan provinces over the fate of the Sanmenxia Reservoir since the south area of Wei River encountered Jumbo floods in 2004,which caused great loss to Shaanxi Province. The dispute went beyond the purely technical level and involved the political level, because the Shaanxi provinces even put forward the notion of abolishing the Sammenxia Reservoir to the National People’s Congress and Chinese People’s Political Consultative Conference. The dispute was thus beyond the scope of administrative mediation by the Ministry of Water Resources or the Yellow River Water Resources Commission. The core of the dispute was conflicting interests between the two provinces. Although technical experts were invited to contribute to the decision-making, they only played the role of “experts offering suggestions”. Government officials made the final decision and the influence of engineers remained relatively weak.

3. Professional engineering ethics versus broader ethical issues. large dams are altering the relationship between humans and nature in China. The exploitation, construction, and maintenance of dams involve the interests of engineers and developers. But dam development also affects the people and wildlife that inhabit the surrounding areas, as well as future generations. Dams transform ecological systems by destroying vegetation and flooding landscapes. Recognition of such broader impacts indicates a need to go beyond any consideration of short-term human interests to include broader social, environmental, and ecological issues related to long-term sustainability.

In many countries, laws requiring the assessment of the ecological impact of dam construction have been adopted and are being enforced to help manage concerns about the environment. China has followed and is applying its own ecological impact assessment law.

Furthermore, dam assessment also increasingly references sociological and anthropological perspectives that were absent until quite recently. In general, the interaction between engineering and society has increasingly become a theme for critical reflection. In the 1990s, for instance, social approval became a core component for the assessment of dam projects by the World Bank, Asian Development Bank, and other international institutions. In January 2002, the Chinese National Development and Reform Commission made societal concerns a top priority, requiring that all engineering projects, regardless of size, address societal issues.

All of the above point to an expanded scope for engineering ethics. To date, however, engineering ethics and engineering decision-making in China remain heavily influenced by technical and economic aspects at the expense of ecological and social impacts.

4. International environmental versus domestic developmental concerns. The international community currently holds a negative opinion of dam development in China. An "anti-dam" trend that originated in Europe and the United States has intensified and has spread to India, Pakistan, and other East Asian countries.

Several studies of dam construction have been organized by environmental protection agencies and related organizations. One example is the report *Dams and Development: A New Framework for Decision-Making* (2000) from the World Commission on Dams of the United Nations Environmental Programme. Another comes from Patrick McCully, campaigns director of the California-based International Rivers Network; in *Silenced Rivers: The Ecology and Politics of Large Dams* (McCully 1996), he claims that a belief in technological determinism along with a lack of ethical engineering has effectively allowed the short-term interests of policy makers and designers to dominate dam-related decision-making. Some environmental groups argue that dam construction constitutes an irreversible "ecological experiment" in which disruptions to geology, hydrology, and the habitats of migratory fish are inevitable.

China's own environmental organizations tend to endorse such foreign concerns and are becoming more and more opposed to the building of dams nationally. But although dam construction in China will continue in order to promote economic development and provide increased welfare for the Chinese people, it is possible to make modifications to protect the environment as well.

Identifying the Sources of These Ethical Issues

The lack of well-developed engineering ethics standards in China makes determining ethical responsibility for projects difficult. As has been observed by philosophers Zhang Hengli and Hu Xinhe (2007), "There are concerns for the missing external engineering context, resulting in ethical problems in engineering practices. And a pluralism of ethics subjects leads to an unclear sense of responsibility and complex relationships in responsibilities in the engineering community."

Different Traditions in Engineering Ethics

The development of engineering ethics in China has some parallels with, and has occasionally been influenced by, engineering ethics in the United States. At one time, engineering in both the USA and China emphasized obligations to clients or employers, with little attention paid to the general public. In the USA, this began to change in the 1950s with a rising concern for professional engineering autonomy and obligations to the protection of public safety, health, and welfare (Mitcham 1994). In China during the same period, the Chinese Communist Party often occupied the place of what in the West would have been termed the client or the public (Zhu Qin 2010). With the development of a more open society, Chinese engineers developed their own concerns for professional autonomy and became interested in engineering ethics discussions in the USA.

Since the 1990s, two new issues have become manifested in engineering ethics in the United States and other western countries. One is an argument that engineers have responsibilities not only to public safety, health, and welfare but also to the protection of the environment (Vesilind and Gunn 1998). Another is a shift from almost exclusive focus on individual or micro-ethical responsibilities of engineers to what has been termed macro-ethics or concern for the organizational frameworks within which engineers function (Herkert 2001). This second shift has been further supported by science, technology, and society (STS) studies.

By contrast, engineering ethics in China has largely continued to emphasize issues of individual responsibility associated with micro-ethics. In the early 1900s, Chinese scholars who had studied in the United States began introducing American engineering ethics guidelines into China. Indeed, the predecessor of the Chinese Institute of Engineers was actually founded there. Su Junbin and Cao Nanyan (2008) examined the 1933, 1941, and 1996 revisions of the ethical responsibilities of engineers in the "Chinese Engineer's Creed" and concluded that the revisions conformed to a pattern of development outlined by Mitcham: from ideals of corporate loyalty through governance by experts to social responsibility. Engineers are also increasingly aware of their responsibilities to preserve the natural environment for future generations. In 1949, the Chinese Institute of Engineers was moved to Taipei. The "Chinese Engineers' Creed" was revised for a second time in 1996 and adopted in Taiwan, but mainland China's engineering community abandoned the creed because of its ideological base. Professional engineers in the People's Republic of China (PRC) have chosen to pursue alternate models.

Currently in the PRC there is increasing concern among public, governmental, economic, and engineering interests to balance economic, social, and ecological perspectives on large-scale engineering projects. But although some large water conservation projects in China have adapted decision-making models found in other countries, the total situation is far from satisfactory. In general the engineering ethics education system remains somewhat weak. By contrast, since the 1970s in the United States, engineering ethics education has been increasingly strengthened; by the end of twentieth century, teaching and research in engineering ethics had evolved into a well-recognized field of discourse that included macro-ethical issues. In early twenty-first-century China, however, teaching and research in engineering ethics remained much less developed, and insofar as it is practiced, it remains largely focused on micro-ethical issues of individual responsibility to promote technical quality and safety.

The Importance of Macro-ethical Contexts

Engineering construction takes place in broad historical and material contexts. Deng Bo (2006), for instance, argues that "the intrinsic elements and endogenous factors of engineering activities consist of specific areas: topography, climatic environment, natural resources and other special natural factors, as well as the region's economic and industrial structure, infrastructure, political landscape, social structure, culture, customs, religions and other social factors." The engineering context includes all such elements in interaction with each other as well as others factors specific to particular contexts. The study of engineering and engineering ethics should consider all contextual factors. Ignoring any of the following factors will give rise to incomplete ethical analyses:

1. Historical contexts. Industrialization and modernization constitute two highly controversial issues related to economic and social development in many countries. Different stages of development have produced different contexts in China and the West.

Dam construction began earlier in Europe and in America than in China. The Hoover Dam, which was begun in 1931 and completed in 1936 in the USA, is the world's first modern large dam; it marked the inception of the large dam construction era. Hoover and related dams made a profound impact in both design and management on the construction of dams in other countries. By the 1980s, however, such large dam construction had largely run its course in the United States and Europe. Not only had most large rivers been dammed, large-scale infrastructure construction and industrialization were being replaced by postindustrial economic developments in the service-oriented and information-based sectors. This enabled the negative social and environmental effects of dam construction to rise to prominence.

For 5,000 years, China has constructed remarkable hydraulic engineering works. One leading example is the Dujiang Weir (constructed during the Warring States Period, 475–221 BCE), which embodied the traditional ideal of harmony and made China for centuries a leader in hydraulic engineering. Since the 1800s, however, water and dam engineering in China has lagged behind that of industrialized countries. Now, in order to meet the needs of economic and social development, especially since the 1980s, the PRC has been rapidly designing and constructing large dams. At present, China has more than 80,000 reservoirs of varying sizes, with more large dams under construction than in any other country. At the beginning of the twenty-first century, however, Chinese dam construction has been increasingly subject to postmodern environmental criticism, sometimes allied with expanded notions of macro-approaches to engineering ethics.

Such criticism fails to appreciate the special historical context that exists in China today, which is not the same as that in the United States or Europe. Recognition of the historical differences can justify "dual standards" with regard to dam construction as well as in the assessment of many other engineering projects.

2. Geographical, social, and cultural differences. Geographical, social, and cultural differences between American, European, and Chinese contexts further justify the development of a distinctive approach to engineering ethics in China. Note, for instance, that China's unique topography makes it prone to frequent floods and droughts that threaten people's lives and security. In the earliest periods of Chinese history, water management was central to governing the country. Some scholars such as the German-American Marxist historian Karl Wittfogel (1957) even argue that China was driven to form a centralized political government in order to construct and manage large-scale water projects.

With regard to resulting social and cultural differences, it is reasonable to ask: Do countries with different social systems need to have different approaches to engineering ethics? Even if the answer is yes, there are further questions of who should be responsible for developing a different approach and what would a different approach look like. The World Commission on Dams report argued that all citizens have a right to decide whether or not dams should be built – and, further, if people object to a large dam construction project, it should not go forward.

Developed and developing countries can reasonably hold differing views on this issue. Developed countries generally agree that widespread public acceptance is required by the principles of social justice. By contrast, leaders in developing countries often argue that such an approach would, as is true today in developed countries, make it virtually impossible to build any more large dams.

But what is social justice? The argument of John Rawls' *A Theory of Justice* (1971), which assumes a kind of atomistic individualism, is not the only way to answer this question. For instance, Robert Paul Wolff (1977) criticizes Rawls from a Marxist perspective as unable to address injustices structured into liberal capitalism. Differences between capitalism and socialism along with those between traditional and modern political decision-making should not be ignored.

Additionally, a careful interpretation of the WCD report reveals that it does not completely reject the construction of all dams. Because each country has its own unique set of circumstances, there cannot be one standard engineering ethics but rather a variety of guidelines. Just as the Chinese Committee on Large Dams suggested, "The policy for dam construction should be based on each country's own conditions and national strengths, and it is neither scientific nor practical to use uniform mandatory provisions to address problems in dam construction" (Xie Guxian et al. 2005).

Toward Chinese Guidelines for Dam Construction

With the growth of dam construction in China, there is a need for standardized engineering ethics. "As China shows its great power in engineering coustruction, there is a considerable gap between the development status of engineering ethics and the actual demands for it" (Guo Fei and Wang Xugang 2009). As China becomes more committed to meeting societal needs, Chinese engineers must take into account population and environment. But in the contemporary political, legal, and economic context, engineers alone cannot solve all problems. To achieve sustainable and sound engineering practices, it can reasonably be proposed that any engineering ethics relevant to large dam construction should take account of at least the following four factors:

1. *The need for national survival and development*. China must establish its own guidelines for engineering ethics. To this end, Chinese engineers need to free themselves of excessive subservience to western approaches. At the same time, they need to seek ways to manifest universal ethical values in a Chinese context.
2. *Quality of life*. The survival of a society depends on its quality of life. When reservoirs flood previously dry areas, they can lead to the relocation of large numbers of people and to basic changes in the natural environment. Large dam construction projects alter the distribution of benefits and risks among different groups of people. If not handled properly, this will also affect social harmony and stability. Ethics needs to reflect not only abstract moral principles but also the real needs of peoples affected by engineering projects.
3. *Demands for safety*. Contemporary engineering practices produce technological, ecological, and social risks. Engineering activities need to include the appropriate measures to avoid these risks. Dams, particularly ultrahigh dams, if they collapse, result in extreme loss of life and property. Therefore, dam design and construction must make safety and security a top priority.
4. *Environmental and sustainable developmental*. Economic growth, quality of life, and environmental protection should be equal concerns for China. While people have a right to improve their lives, national development is an irreversible process. By respecting its resources, China can contribute to the protection of the Earth's ecological integrity and biological diversity.

General Approaches to Dam Construction Ethics in China

Taking these four factors into account, it is also reasonable to argue that engineering ethics in China should adapt and extend developments in macro engineering ethics. At the same time, this must not be done without full attention to China's distinctive historical, geographical, social, and cultural contexts. Reflecting the long historical tradition of the Chinese ideals of harmony found in various Daoist, Confucian, and Marxist traditions, engineering ethics in China should also promote a harmony in society and with nature in pursuit of a balance between economic development, social benefit, and environmental protection. Within such a general framework, the following further three specific actions deserve consideration:

1. *Seeking a balance between ethical responsibility and pluralism*. Engineering ethics must appreciate the ways that general responsibility is distributed throughout a diversified engineering community. Although one of the roles of the engineer is to be aware of and address risks, attention must also be given to the ethical responsibilities of multiple stakeholders in an engineering project.
2. *Coordinating responsibilities in different stages of a project*. During the decision-making stage of a project, government officials responsible for approval and oversight should consider the long-term impacts on the economy, society, and the environment. Engineers should carry out technical and design requirements as well as predict possible negative consequences, from the bidding process to the design work and construction. The business community must consider not only economic interests and profits, but also environmental and security issues. During the construction phase, the focus should be on responsibilities to state workers, including those who will ultimately be involved in dam operation and maintenance. And the public should share some responsibility for reporting their concerns to the engineering project community. The responsibilities involved in dam construction projects deserve to be shared by all stakeholders.
3. *Strengthening engineering ethics education*. Only with attention to China's national context can the ethical norms and guidelines of engineering ethics be established and improved. Engineering activities must be consistent with government statutes, societal needs, and environmental standards so that current ethical problems can be addressed. Specifically, we need to accelerate the development of engineering ethics education by developing courses related to engineering ethics, conducting training in ethics, and improving the ethical awareness of engineering students, thereby promoting the institutionalized development of an engineering ethics appropriate to the Chinese context and relevant in particular to large dam construction.

Conclusion

The establishment of sound ethical guidelines can help mediate the opposing perspectives of pro-dam and anti-dam advocates, balancing issues such as the needs of economic growth and environmental protection, as well as the interests of all people whose lives are affected. At the same time, the future development of engineering ethics in China must be based on the Chinese context. By expanding the scope of ethical responsibility for engineers, actively paying attention to responsibility and obligations within different communities, we are likely to be able to offer better guidance in engineering practice.

We have much to learn from both the successful experiences and the lessons of failure since the founding of modern China. Linking outstanding teams of engineers with long-term planning, scientific decision-making, well-ordered ethical thinking, and citizen-oriented problem solving that focuses on issues such as immigration and ecology, dam projects in China will be able to contribute to national needs.

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Chapter 20
The Development of Railroads in the United States and China

Nan Wang

Abstract The railroad, as the first form of transport to utilize nonhuman or animal energy resources, is one of the most revolutionary inventions of all time. While many books and articles have been written about railroads from historical, economic, and societal perspectives, the present analysis offers a more comparative evaluation of their development in the United States and China. Five aspects that are examined include planning, finance, standardization, management, and pricing. This comparison indicates that many factors – from economic and political, to technological, managerial, institutional, military, cultural, environmental, and more – can influence railroad development. It also offers a window on how engineering can function differently in two quite different societies.

Keywords Railroad • Development • History • United States • China

Railroads inaugurated a revolutionary transformation in human transportation. The railroad was the first means of transport to make use of the steam engine, a new source of energy that powered the Industrial Revolution in production. The speed of railroad adoption anticipated changes that would mark the development of automobiles and airplanes. Across the globe, railroads have also been significantly associated with economic development and so, for a multitude of reasons, deserve special socio-philosophical reflection.

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The Development of American Railroads

Although developed largely in England, where their commercial feasibility was demonstrated in 1828, US railroads also experienced early dramatic growth (Taylor 1964, p. 74). That same year, the first US railroad, a 13-mile track between Baltimore and Ohio, was chartered and, within 2 years, became operational. Railroad construction proceeded at a rapid rate over the next two decades prior to the start of the US Civil War (1861–1865).

When gold was discovered in California in the 1850s, mass migration created an urgent need for railroad development in western America. By 1860, the total length of railroad track reached over 30,626 miles, while in the east of the Mississippi, similar growth was occurring (Taylor 1964, p. 86).

During the half-century following the Civil War, railroads played a remarkable role in the process of the American shift from an agrarian to an industrial nation. Federal, state, and local governments encouraged the development of railroads by supplying tax credits, government loans, and land grants. It was the golden age of American railroads. Successive bursts of railroad construction over a half-century increased the American rail network more than sevenfold. A network that in 1865 amounted to 35,085 miles had, by 1916, reached an all-time high of 254,037 (Stover 1961, p.104). At the time, this amounted to more than the total of Western European railroad track and nearly one-third of the length worldwide. Railroads monopolized the national passenger and freight traffic and became a primary infrastructure for the national economy.

Since the First World War, however, development and use of American railroads has declined. Major causes include state and federal regulations that began to be developed in the 1870s and competition from new modes of transport such as the automobile, airplanes, and pipelines, which began appearing in the late nineteenth and early twentieth centuries.

As the use and profits of railroads in freight and passenger traffic declined through the 1960s, plans for further expansion were abandoned and lines eliminated. By the late 1970s, the total mileage of railroads was reduced to 179,000 miles, and the remaining 25% of US railroads were bankrupt. American railroads were experiencing their worst financial crisis since their emergence.

But in the 1980s interest in railroad development rose again, due to the adverse effects on societal life of especially automobiles and the increasing importance of environmental protection. The US government adopted a series of deregulation policies, beginning in 1980 with Staggers Rail Act, to aid in the revival of railroads. Deregulation significantly improved the economic benefits of railroads. Changes in the global market and the rise of oil prices since the twenty-first century boosted American railroads even further.

Planning

With some exceptions, American railroads are privately owned and operated. Profit is what drives free enterprise. A historian, however, must be cautious assuming that the planning of American railroads has always been made simply in pursuit of economic profit; political influences have regularly disturbed free market principles (Chuinai 1987, p. 57). The US government has often affected the planning of railroads in order to advance perceived local or national interests by providing direct assistance to private corporations.

In the 1820s when Baltimore found that the improvement of transport facilities played an important role in Philadelphia's commercial success, the local government began to develop new canal and rail projects. They considered these developments their duty. A report on the Baltimore and Ohio railroad by a commission of Baltimore said:

> Baltimore lies 200 miles nearer to the navigable waters of the West than New York, and about 100 miles nearer to them than Philadelphia…. and by far the most practicable route through the ridges of Mountains that divide the Atlantic from the western waters is along the depression formed by the Potomac in its passage through them. Taking then into the estimate the advantages which these important circumstances afford to Baltimore, in regard to this immense trade, we again repeat that nothing is wanted to secure a great portion of it to our city, but a faithful application of the means within our own power.
>
> (Dobbin 1994, p. 38)

The federal government was not a tacit spectator especially in the planning of transcontinental rail lines. In the 1860s, the suggestion of a transcontinental railroad became an important issue in Congress. Advocates argued that Washington act to promote national interest just as local governments had promoted local interest. To ensure that cross-country railroads were feasible before committing federal resources, Congress assigned the army to research possible routes. Congress then provided land grants and loan guarantees to four transcontinental lines to speed up the development of transport links to the West (Dobbin 1994, p. 39).

Finance

Money raised from stocks and bonds by private investors provided the majority of capital used to build American railroads. One-quarter of private investors were foreign. The English in particular were particularly prominent in early railroad development (Shunguo 1992, p. 168).

Being quite dependent on private capital, the US government created new financial instruments. First, second, and third mortgage bonds, as well as debenture and convertible bonds, were issued to meet the growing needs of the railroad industry.

By the outbreak of the Civil War, the New York financial district had become one of the largest and most sophisticated capital markets in the world (Chandler 1977, p. 93).

State and local governments provided liberal provisions in railroad charters – for building railroads, supplying needed money and credit for private construction, and granting lands. At the same time, the federal government provided parts of the public domain to railroad companies by granting lands alongside the route of the railroad. By 1943, the nation's railroads had received land grants from nine states amounting to another 48,883,372 acres and full title to 131,350,534 acres from the federal government (Stover 1961, pp. 88–89).

Standardization of Technology

Practically from the beginning, US railroad construction lacked uniform technological standards and operated without government intervention. The diversity of track gauges seriously hindered their efficiency, multiple time zones prevented the coordination of interlines, varied signal standards caused frequent accidents, and the lack of basic safety features threatened the personal well-being of employees and customers. Though its development was rapid, American railroads did not become an integrated network before the Civil War.

Then, during the second half of the nineteenth century, 22 professional railroad associations emerged including the American Association of Passenger Traffic Officers, the General Time Convention, and the Association of Track and Structure. These alliances consisted of skilled and managerial-level employees, but were organized by specific skill sets rather than by employer. They were created to standardize various industry aspects, including scheduling, signaling, car connection safety, uniform gauges, braking procedures and devices, and stronger bridges (Kennedy 1991, pp. 145–146).

Management

Administrative challenges for US railroads first surfaced in the 1850s when changes began to appear in railroad operations. Changes such as an increase in traffic volume, growth in employee numbers, and the emergence of the large railroad made it clear that inadequacies in current managerial methods were affecting transport safety and operational efficiency. As a result, management began to create innovations in organizational structure, accounting methods, and statistical analyses:

> The railroads were, then, the first modern business enterprises. They were the first to require a large number of salaried managers; the first to have a central office operated by middle managers and commanded by top managers who reported to a board of directors. They were the first American business enterprise to build a large internal organizational structure with

> carefully defined lines of responsibility, authority, and communication between the central office, departmental headquarters, and field units; and they were the first to develop financial and statistical flows to control and evaluate the work of the many managers.
>
> (Chandler 1977, p.120)

The period from the 1870s to the beginning of the twentieth century was a period of competition and consolidation, leading to the birth of the large railroad. Its emergence required additional innovations in organizational structure. This time, not only management but also investors and speculators were engaged in seeking solutions. Suddenly, a divisional system became popular among American railroads (Chandler 1980, p. 16).

Pricing

Early American railroads were operated liberally in the context of national economics. But with their rapid development in the latter half of the nineteenth century, intense competition grew, causing serious issues. These included rate wars, rebating, discrimination within both long- and short-haul pricing, and operation safety. After the Civil War, complaints against these problems led to a growing demand for regulation.

At first, several states passed laws to regulate railroad rates. Then during the 1880s, railroad regulation moved from the state to the federal level (Stover 1961, 130). In 1887, the Interstate Commerce Act was signed by President Cleveland and the Interstate Commerce Commission (ICC) was created. Originally, the responsibility of the ICC was to ensure that all interstate rates be "reasonable and just" and without discrimination. The Hepburn Act, passed in 1906, extended the powers of the ICC to include common carriers and was empowered to establish "just and reasonable" maximum rates. The Transportation Act of 1920 greatly increased the power and scope of the original ICC. Now the ICC's jurisdiction included establishing minimum as well as maximum rates, supervising all railroad-security issues, and that mergers and consolidations be subject to ICC approval. Although these stringent railroad regulations provided protection for consumers, the US railroad industry declined.

Since the 1970s the US government has adopted a number of measures to improve the operation of American railroads. In 1976, the Railroad Revitalization and Reform Act was approved. This act gave railroads more commercial freedom in some respects, for instance, in rates, abandonments, and mergers. In 1980, Congress deregulated rates and other aspects of the railroad system as part of the Staggers Rail Act. In 1996, the Surface Transportation Board (STB) created by the Interstate Commerce Commission Termination Act of 1995 further redefined and adjusted the contents and scope of regulation. All of these reforms promoted American railroads at a time when rail traffic was in decline.

The Development of Chinese Railroads

The railroad is an illegal exotic for China (Zenglin 1999, p. 1). China's first commercial railroad was the Shanghai-Wusong route, built by the English in 1876. The following year this unauthorized 15-km railroad was purchased and then destroyed by the Qing government. It was believed that it would disrupt the natural flow of the geomantic omen,[1] which could weaken their natural defenses and cause harm to their homes and land (Shixuan and Wenshu 2000, p. 7).

With the growing desire to strengthen and enrich China (the objective of what is known as the Self-Strengthening Movement), to better compete with the West, the Qing government built its first railroad, the 10-km Tangxu railroad in 1881. In 1887, the Tangxu expanded to 130 km, and over the next 2 years, three more routes were built. By the end of the decade, the length of Chinese railroads measured 480 km.

In order to maintain its rule after the first Sino-Japanese War of 1895, the Qing government's New Deal made railroad construction a matter of prime importance. (Shixuan and Wenshu 2000, p. 20). In the midst of financial crisis, the government relied heavily on foreign borrowing with additional clauses. The first climax of western powers plundering the right of Chinese railroad happened. Chinese people started to recapture the right of railroads and the private railroads in 1903 (Zenglin 1999, p. 5). By the end of the Qing government in 1911, the total distance of Chinese railroads spanned more than 9,000 km.

When the Republic of China was founded in 1912, a surge in railroad planning emerged. But because the Beiyang government had nationalized private railroads, suppressed appeals by local governments to build more, and, again, was relying on foreign money, attempts by Western powers to control Chinese railroads once again emerged (Zenglin 1999, p. 4). During the Beiyang government's 15-year reign, only 3,900 km of new line was laid.

In 1927, the National Government was founded. It viewed building railroads as a key component in revitalizing industry. By supporting its development, construction expanded. Between 1932 and 1937, 3,600 km of new rail line were constructed (Yonggang 1997, pp. 107–109). During the period of the Anti-Japanese War, with the exception of 5,700 km built in three northeastern and Rehe provinces and 900 km in northern China and Hainan Island built by the Japanese during their occupation of China, the National Government constructed just 1,900 km of line in southwest and northwest China. By 1946, the total length of Chinese railroads reached 22,600 km (Shixuan and Wenshu 2000, pp. 490–491). Only 11,000 were open to traffic by 1949 due to the destruction caused during the People's Liberation War from 1946 to 1949.

After the establishment of the People's Republic of China in 1949, Chinese railroads entered a period of growth. Within 3 years, older lines were restored, and large-scale

[1] The geomantic omen theory refers to a comprehensive principle of appraisal of environmental considerations in the planning and designing of buildings in ancient China such as topography, physiognomy, view, and climate and ecology.

railroad construction was being planned. By 1965, the total operating distance increased by 74.3% reaching 38,025 km. Although development was restrained by the Great Proletarian Cultural Revolution from 1966 until 1976, it never stopped. By 1981, the operating distance was 50,181 km.

With the opening and reform of the Chinese economy since the end of 1970s, expansion progressed quickly. The sudden increase in freight and passenger traffic created a great need for more transport capacity. The 1980s thus saw a crusade to build more railroads. By 1996, the total distance of railroads had reached 64,900 km, and a network connecting the east to the west and the north to the south was in place. Over the next decade, China launched a campaign to increase rail speed. Passenger and freight trains averaging speeds of 200 and 120 km/h or higher were put into operation, which increased speed three times compared to what it was in the 1990s. China now had the world's longest high-speed rail network with approximately 7,431 km (4,617 miles) of routes in service as of September 2010, including 1,995 km (1,240 miles) of rail lines with top speeds of 350 km/h (220 mph) (Lan 2009).

Planning

Nearly all Chinese railroads were state-owned from the beginning. The Chinese central government was responsible for planning and development. With the lack of economic and industrial development, the construction of railroads in modern China relied largely on foreign investments before new China was established. Successive governments depended on the support of foreigners with harsh conditions for the construction of a national railroad. It provided great opportunities for Western powers to plunder the right of railroads. Chinese national governments of that time were often no more than puppets of foreign powers:

> Among the 9,618 kilometers Chinese railroads established by 1911, 8,950 were operated or controlled by Western powers. By 1937, the amount reached to 19,070 kilometers with a total mileage of 21,036. Following the victory of the Anti-Japanese War (in 1945), China regained the right of 10,556 kilometers railroads from Japan and Germany, but 8,538 kilometers were still operated or controlled by Western countries. Moreover, Western powers took advantage of their situation to plunder mineral and agricultural wealth and took control of policing via their control of the railroad system.
>
> (Yonggang 1997, p. 3)

On January 10, 1949, the Chinese People's Revolutionary Military Commission announced the establishment of the Ministry of Railways of the Central Military Commission (renamed Ministry of Railways of People's Republic of China on October 1, 1949). Its duty was to oversee the construction, management, and operation of the nation's railroads.

Adopted at the 15th Session of the Standing Committee of the 7th National People's Congress of People's Republic of China on September 7, 1990, the Railway Law of the People's Republic of China emphasized this in Article 3:

> The competent department in charge of railways under the State Council shall be responsible for railway affairs throughout the country, implement over the State railway network

> a transport control system which is highly centralized and under unified command, and shall provide guidance for, coordination among, supervision over and assistance to local railways, industrial railways and railway private sidings.

Finance

Typically, funding for railroad construction could be obtained by government grant, private investment, or foreign debt. However, due to weak political and poor economic circumstances prior to 1949, various Chinese governments lacked funds. Private investments were often resisted by Western powers or the Chinese comprador class. It was widely thought that foreign bond would lead to foreign control of Chinese railroads, but foreign debt may not (Congbing 2006, p. 445). Therefore, foreign debt became the principal source of funding for the construction of railroads in old China. Of the 85 foreign debts (about 374,560,965 liang of silver) acquired by the Qing government during its reign, 37 (about 318,147,297 liang of silver) supported railroad finance. During the rule of the Beiyang government, nearly 4,000 km of new line was financed by foreign debts (Pusen 2005).

Prior to the first Sino-Japanese War, foreign debts of Chinese railroads were small enough that they could be paid off quickly. As the Qing government realized how important railroads had become to China by the start of the war, they began to borrow foreign funds on a larger scale. Because the East was prosperous during this period and the West ambitious to carve up modern China, bond issuance and railroad construction operated smoothly. Then, with the political instability that followed, the value of Chinese railroad bonds began sinking in the European market. Focused on stability and with European measures to encourage exports, again, beginning in 1932, Chinese railroads began to acquire foreign debts. These debts, however, were only used to purchase materials and for funding construction (Ruide 1991, pp. 6–9).

The foreign debts that financed modern Chinese railroads were not typical loans. In addition to standard items – interest rates, discounts, and payment deadlines – they included provisions such as operational rights, selection of management, and the purchase of materials. While foreign debts to some extent accelerated the progress of modern Chinese railroads, they also deepened the level of dependency of the state.

In modern China the government was dependent on financing. Before the 1980s, profits and taxes from the Ministry of Railways were reinvested into the railroads. When economic responsibility was shared by the entire industry beginning in the 1980s, the majority of investments in railroads came from industry profits. Still, railroads encountered serious fiduciary challenges. In 1991, in order to provide railroads with stable funding, the government began collecting money within a railroad construction fund by imposing duties on freight and furnishing credit to railroads. In recent years, railroad bonds have been used as a method of financing in China. They are issued by the Ministry of Railways and guaranteed by the railroad construction fund.

Standardization of Technology

In the nineteenth century Chinese railroads were funded, and to an extent controlled, by Western powers who wanted their standards and materials to be used. China did not develop any standards of technology by itself. There existed various ones at an early stage of Chinese railroads. This greatly hindered railroad transport and worsened with the expansion of railroads. For standardizing the railroads, the Department of Transportation founded the Railroad Technology Standards Committee in May, 1917. This committee formulated and publicized the engineering and mechanical standards of the railroad bridge, gauge, track, locomotive, etc., based on the metric system, and established traffic control signal indications (Yonggang 1997, pp. 97–98). During the period of the National Government 1925–1948, domestic engineers took the place of foreign engineers and supervised all railroad projects. It promoted the gradual unification of technical standards, though some differences still remained (Ruide 1991, p. 6).

Technical standards for Chinese railroads were first developed by the Regulations on Railway Technical Management and published by the Ministry of Railways of the People's Republic of China in June 1950 (Zenglin 1999, p. 30). Basic principles included working methods, operational procedures, design and building requirements, inspection, maintenance, use of transportation facility, and the major responsibilities of staff. The Ministry of Railways established a series of new rules and regulations on standards of technology later on.

Management

Early in the development of Chinese railroads, institutions such as the Railways Corporation (1896) and the Bureaus of Railroads (1906) were established to set policies. But the ability to secure foreign money for further development of the national railroads was still their top priority. Because each line's financial needs varied, they were managed by several departments under the central administration.

As the number of lines increased, it hindered communication and decreased management's efficiency. In 1928, the National Government established the Ministry of Railroads to oversee them. To promote growth in the industry, the ministry adopted management practices that were successful in other enterprises and incorporated them into new railroads (Ruide 1991, pp. 82–83).

The central administration of railroads in modern China did not manage all railroads the same way during the periods of the Qing Dynasty, Beiyang government, or early National Government. This was due to strong local influences, varying geographical location of the lines, and different policies. Gu Mengyu, Minister of Railroads, in a speech in 1932 complained:

> Ministry of Railroads provides nominal administration to national railroads. The number of railroads it supervises is too small. As far as the Guangdong Province is concerned,

> Guangjiu, Guangsan, Guangshao, these three lines severed their links with the Ministry within six months. We do not know the situation of their operation or their employees or managers. But we should pay off their foreign debts.
>
> (Ruide 1991, p. 86)

Chinese railroads have been unified under a centralized government and monitored by the Ministry of Railways of People's Republic of China since 1949. This management style played an important role in their development, especially during the recovery of the national economy and the Great Proletarian Cultural Revolution. It brought to the forefront the realization that railroads cannot operate independently and assume sole responsibility for their profits or losses. During the past 20 years, focus on defining property rights, specifying rights and responsibilities, separating ownership from daily management, and adopting modern technology has been the target for reform of the Chinese railroad industry.

Pricing

In the early years, the pricing of Chinese rail was largely based on regulations made by lenders. In the meantime, the government established Huojuan, a special railroad tax, to increase state revenue. Being controlled by the government since 1921, military forces, with no understanding of railroad operation, increased the freight at will. In addition, they set up barriers along the railroads to collect a tax on goods transported by rail. During this time, taxes and barriers were exorbitant. This caused the price of freight and tax in the 1920s to be much higher than that of the late Qing Dynasty. Lijin (a trade tax in modern China) was eliminated by the Ministry of Finance in 1931. Although the number of barriers declined, some still existed (Zenglin 1999, pp. 55–71).

After the founding of the People's Republic of China, in May of 1949, the Ministry of Railways of the Central Military Commission held its first conference to determine railroad transport pricing. It defined the uniformed standards of classification of goods and freight tonnage and the principles of pricing. Two months later, rules on passenger and freight transport pricing were issued and carried out. The national railroads have implemented pricing and regulations ever since.

Summary

This brief comparison makes the following points:

(1) Planning. While the majority of railroad planning in the United States was done by private investors, the government was somewhat involved. On the contrary, within China the government controlled planning.

(2) Finance. In the United States, the diversity of investments, including private, foreign, state and federal governments, and the variety of means of financing, including stocks and bonds, provided railroads with an ample and stable financial support. In China, however, the conditional foreign debts, which were the primary source of railroad funding before 1949, hindered the development of early railroads. The Chinese government, which provided the majority of financing since the foundation of the People's Republic of China, restricted the development of railroads.
(3) Standardization of technology. Professional associations played an important role in completing the task in the United States, while in China this was accomplished by the government.
(4) Management. American railroad companies adopted managerial innovations according to the developmental needs of its railroads. Chinese companies are moving in this direction.
(5) Pricing. American railroad companies control pricing but are regulated by government. In China, the government controls pricing exclusively.

This brief comparison shows us that multiple factors influenced the development of railroads, such as economic, political, technological, managerial, institutional, military, cultural, and environmental. Technological factors played an important role in the development of railroads, but non-technological factors often had much more impact than technological. During the period of modern China, a weakened political position was the greatest barrier for railroad development. Clearly, the successful development of railroads in any country in the world depends on the comprehensive function of all of these factors.

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Chapter 21
Engineering Leadership

Mike Murphy and Eugene Coyle

Abstract By 1921 the American sociologist Thorstein Veblen in his book *The Engineers and the Price System* argued for a technocracy in which the welfare of humanity would be entrusted to the control of the engineers because they alone were competent to understand the complexities of the industrial system and processes and thereby optimise and maximise its output. This chapter sets out to explore the extent to which Veblen's technocratic leadership thesis has come to pass. We first review the role of the engineer in society and in the context of Europe, the USA and China and examine the influence of the engineering profession on the management and economic welfare of nations. Second, we review trends in engineering education and formation in Europe, China and the USA and the substantive developmental role of the *Grand Écoles* in eighteenth-century France. A comparison is made between the economies of Ireland and China, in the context of their recent economic performance. Third, a review of commentary on the interconnectedness of world economies and shift in economic power from nineteenth-century United Kingdom market dominance to twentieth-century United States supremacy and to present day emergence of China as the world's second largest and fastest growing economy is made in the context of the role of engineering leadership. We finally ponder whether a hybrid political environment, with a blending of meritocracy with technocratic leadership and moderated by nonengineering influences, might be a recipe for sustained economic success of nations.

Keywords Technocratic leadership • Engineering profession • Engineering education • Political economy • Captains of finance

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Introduction

> 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.
>
> (Thorstein Veblen 1921, p. 44)

The national economic contexts of Ireland and China in the autumn of 2011 are contrasting and different. China has now become the world's largest exporting nation and its economy (GDP) is second only to the United States in size, at $10 trillion in 2010 figures. The growth rate in GDP has been 8% or higher since the year 2000. On the other hand, Ireland has a relatively small economy at $172 billion in 2010 figures, or just over 1% the size of the Chinese economy. Despite recent years of prosperity that were characterised as a *Celtic Tiger* economy, Ireland went into recession in 2009 as a result of a collapse in the construction sector of its economy. In March 2009 Ireland's economic rating was downgraded from AAA, and within 20 months the Irish government requested a bailout from the International Monetary Fund. One estimate puts Irish national debt currently at over €113 billion for a population of just under 4.5 million people or €25,000 for every person in the country. Irish gross domestic product (GDP) has fallen each of the last 3 years.

From an Irish perspective, within the space of three short years, what was originally characterised as a bank liquidity problem evolved rapidly into a bank debt problem, progressed to a bank solvency problem and was to become a national debt problem when the Irish government guaranteed all Irish bank debt. It is currently now a national solvency issue because it is not clear that Ireland will be capable of repaying this debt (see, e.g. Michael Lewis writing in Vanity Fair (Lewis 2011)).

In Ireland, Irish political leadership allowed the banks and their risk taking to take control in such a way that the bank investors (bond holders) are guaranteed and thus able to walk away from the chaos financially protected whilst every Irish citizen is required to assume the total debt of the banks. Would a different class of leadership, for example, leadership by engineers, have done a better and more honest job of managing the economy? In 1921 Thorstein Veblen argued that 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' (Veblen 1921, p. 44). Perhaps because of the nature of engineering education – at its heart shaping forces to serve some end in an optimal manner – would engineers as leaders have acted more responsibly and demanded more accountability from our captains of finance? Here again Veblen makes the observation that 'engineering begins and ends in the domain of tangible performance, and that commercial expediency is another matter' (*ibid*. p. 47).

In a 2005 article Tenner wrote that 'The argument that gained credence in 19th-century France and was echoed in other regimes is that a state must be guided by a scientific and technological elite' (Tenner 2005). Certainly modern China would appear to provide a supporting example for Veblen's thesis: the Chinese economy has developed steadily and the majority of its senior political leaders have been educated as engineers. This chapter sets out to explore whether it is the case that modern China, and in particular its leadership, embodies Veblen's technocracy argument and is successful as a consequence and that Ireland, lacking a discernable technocracy, has suffered as a consequence. We suggest that France provides a western example of a moderating technocracy.

Engineers, Captains of Finance and Investment Bankers

From the perspective of a post-First World War economy – and the horrors of that conflict must be borne in mind when analysing his thesis – Veblen observes that the industrial system had become a 'system of interlocking mechanical processes' and 'an organization of mechanical powers and material resources' and consequently it 'lends itself to systematic control under the direction of industrial experts, skilled technologists, who may be called "production engineers"'. Veblen argues that the system, indeed the material welfare of society (specifically 'the material welfare of all the civilized peoples'), could only function at its best if it is run by engineers all working together harmoniously rather than at cross-purposes in an interdependent manner. 'Politics and investment are still allowed to decide matters of industrial policy which should plainly be left to … production engineers driven by no commercial bias' (Veblen 1921, p.35).

Notwithstanding this, Veblen asserts that statesmen thwart this potential optimality by working to the advantage of individual countries and likewise the captains of finance work at cross-purposes to an optimal system by colluding to benefit vested interests. 'It is essential that that corps of technological specialists who by training, insight, and interest make up the general staff of industry must have a free hand in the disposal of its available resources, in materials, equipment, and man power, regardless of any national pretensions or any vested interests' (Veblen 1921, p.35).

Through the industrial revolution, there was no separation or division required between industrial experts and those who managed the business. However with increasing complexity and specialisation, 'progressive differentiation' developed which served to delineate 'those who designed and administered the industrial processes from those others who designed and managed the commercial transactions'.

Because of increasing complexity, the industrial system came to a branch point with regard to how the system was developed and managed. Greater technical specialisation was required to inform production decision making, and this required special training, hands-on experience and a focus on technical issues. But by both achieving this training and focussing on technical issues, this ensured that the engineers became the employees of the 'captains of finance', namely those whose role it was to manage the commercial aspects of industry.

> But gradually, with the passage of time and the advance of the industrial arts to a wider scope and a larger scale, and to an increasing specialization and standardization of processes, the technological knowledge that makes up the state of the industrial arts has called for a

> higher degree of that training that makes industrial specialists; and at the same time any passably efficient management of industry has of necessity drawn on them and their special abilities to an ever-increasing extent.
>
> (Veblen 1921, p. 40)

According to Veblen, technology is a 'joint stock of knowledge and experience'. Consequently it requires 'trained and instructed workmen' and also 'a corps of highly trained and specially gifted experts'. The development of the education system for these technical experts is described in the next section.

Veblen argues that, in turn, the captains of finance – disparagingly referred to as 'one-eyed captains of industry' – lost control to investment bankers, in part because of the increasingly large scale of corporate enterprise and its necessary financial underwriting through securities. These investment bankers continue to control the technical experts. For our purposes we will characterise this as the expert reporting to the nonexpert, a concept that we shall return to shortly.

Up to this point Veblen has developed the argument that without engineers the entire industrial system would grind to a halt and further that the efficiency of enterprises is significantly compromised by the vested interests of commercial managers and investment bankers. Why do engineers, the technical experts, not organise into a 'self-directed working force'? According to Veblen, engineers have begun to become 'class conscious' in particular as they consider how inefficient the industrial system is, a system of which they are an essential part, but which in no sense is managed for the optimal benefit or needs of the community. They already, but perhaps not fully consciously nor collectively, understood that they controlled the mechanisms of productive industry. The educational system was broadly recognising and responding to the requirements to develop specialised training, acknowledging the importance of the engineers' role. What then if they organised? However, before we can attempt to answer this we must take a step back and provide some context on how the world got to be where it was when Veblen was developing his thesis.

The Interconnectedness of the World Economy

> The history of the world economy since the Industrial Revolution had been one of accelerating technological progress, of continuous but uneven economic growth, and of increasing 'globalisation', that is to say of an increasingly elaborate and intricate worldwide division of labour; an increasingly dense network of flows and exchanges that bound every part of the world economy to the global system.
>
> (Hobsbawn 1994, p. 87)

Let us review briefly how the world came to be so interconnected. In the latter half of the nineteenth century, years of industrial development together with free trade policy had greatly benefitted Britain. Its industrial growth had averaged 3–4% per annum for most of the century. The outcome of which was that the United

Kingdom was the most highly industrialised country in the world. 'British export performance in engineering machinery, textiles, iron and steel and coal' made its balance of payments positive, despite the fact that imports of food and raw materials were growing at a faster rate than exports (Robbins 1983). But even at the height of empire, concerns were increasing that technology was mobile and according to Robbins that a 'distinctive set of circumstances had produced an industrial revolution in Britain – but it could occur elsewhere. Techniques of production could be mastered by foreigners and there was no reason why they could not improve upon British inventions'. As one example, in 1879 Britain produced more steel than the rest of Europe combined. By 1886 the USA had surpassed Britain, followed by Germany surpassing Britain in 1893. Over this period, British steel manufacturing continued to grow. But the continued growth in British steel masked the underlying global economic shifts that were taking place. Consolidation and concentration became more frequent within British industry as companies tried to leverage economies of scale and compete against external competition.

By the 4th quarter of the nineteenth century, the United States was booming. During this period many significant technical inventions originated in the USA such as machine tools, the telephone, electrical generation and distribution and home products such as Singer sewing machines, Yale locks and the typewriter. Bryson has captured this era very well when he writes 'Europeans viewed America's industrial ambitions with amusement, then consternation and finally alarm. In Britain, a National Efficiency Movement arose with the idea of recapturing the bulldog spirit that had formerly made Britain pre-eminent. Books with titles like *The American Invaders* and *The 'American Commercial Invasion' of Europe* sold briskly. But actually what Europeans were seeing was only the beginning' (Bryson 2010, p. 313). What in fact was occurring was the inexorable shift of economic power and dominance from Great Britain to the United States.

Events at the end of the nineteenth century have resonances with the economic situation that opened our chapter. In 1890 the British investment bank, Baring Brothers, overextended itself through bonds to finance Latin American debt and required rescue by the Bank of England.[1] British banks invested heavily overseas in this period with no government interference. The British government saw its role as trying to ensure fair competition for British business and pursued free trade to that end, even when it was clear that British interests were suffering to the ideal of free trade and British bank investments in other countries (Robbins 1983).

In tandem with the technological developments in the United States was the education of engineers and technologists. This was necessary as the United States had pioneered the systematic organisation of mass production and as skilled engineers were required for factories engaged in design, development and production using scientific principles.

[1] One hundred years later in 1995, the company collapsed through futures trading within the space of a single weekend.

We arrive at a crossroads. As Veblen wrote, the Great War – the war to end all wars – is over. The boundaries of empires are being redrawn at the Paris Peace Conference in 1919.[2] Monarchies are in upheaval and new political regimes are on the rise. The industrial revolution has yielded to industrialisation and increasingly complex manufacturing processes. The education system is transforming in response. The education of engineers occurs in elite schools. The profession is organising. Has the hour of the *Engineer as Leader* finally arrived?

Economic Collapse

It was not to be. The interwar years were to prove decisively negative for capitalist economies. In describing these years as *the age of catastrophe*, Hobsbawm (1994) has written that 'a world economic crisis of unprecedented depth brought even the strongest capitalist economies to their knees and seemed to reverse the creation of a single universal world economy, which had been so remarkable an achievement of nineteenth-century liberal capitalism' (Hobsbawn 1994, p. 7). In short, integration and globalisation of the economies of the world retreated from the outbreak of the First World War. Population migration slowed considerably over this period. 'Between 1927 and 1933 international lending dropped by over 90 per cent. … Each state now did its best to protect its economy against threats from outside, that is to say against a world economy that was visibly in major trouble' (Hobsbawn 1994, p. 89).

The end of the Great War provided a temporary boom, but this was short-lived as countries like Great Britain sought to handle approximately three million demobilised service men. Unions saw their power increase. However, 'prices and the boom collapsed in 1920. This undermined the power of labour – British unemployment never thereafter fell much below 10 per cent and the unions lost half their members over the next twelve years – thus once again tilting the balance firmly towards the employers' (Hobsbawn 1994, p. 89). The monetary system collapsed with western countries deflating their currencies in attempts to regain stability. Germany's currency became worthless resulting in its industry becoming starved of working capital, and the country relied increasingly on foreign loans, which added to the burden of £22 billion in war reparations that Germany was required to repay under the Treaty of Versailles. This created economic conditions that made Germany receptive to fascism.[3]

[2] Of interest, a small country called Ireland made representations in Paris to have its sovereignty recognised by the great powers. This recognition was not forthcoming, and Ireland went through a war of independence followed by a civil war both of which occurred while Veblen was writing 'The Engineers and the Price System'.

[3] Germany fully cleared its First World War debt in 2010 when it made its final payment under the Treaty of Versailles.

Post-war unemployment in most of Western Europe remained extremely high. Unemployment was more controlled in the Soviet Union. Prices for goods continued to collapse, even with stockpiling in attempts to maintain price stability. Industrial output capacity was greater than markets could consume. 'At a time when world trade fell by 60 per cent in four years (1929–1932), states found themselves building increasingly high barriers to protect their national markets and currencies against the world economic hurricanes, knowing quite well that this meant the dismantling of the world system of multilateral trade on which, they believed, world prosperity must rest'. 'In a single sentence: the Great Slump destroyed economic liberalism for half a century' (Hobsbawn 1994, pp. 94–95).

Here then is a rationale for the failure of engineers to assume the leadership role argued for by Veblen. The engineers were in a position to optimise efficiency and output at exactly the time when such efficiency and output were counterproductive given the collapse of global trade that was occurring in the world. Consequently, in western capitalist economies, industrial leadership remained with those who controlled output and prices, identified by Veblen as the investment bankers. Experts continued to be managed by nonexperts.

The Education of Engineers in Europe and the USA

A brief recall of early developments in engineering education in France and other European countries on the one hand and England and the United States on the other is important in contextualising the emergence of the engineering profession in Europe and the United States. Context and comparison with the education of engineers in China is addressed in the ensuing section. The emergence and advancement of engineering education through the eighteenth and nineteenth centuries is well documented, with scholarly contributions of pivotal historical developments in France, Germany, England, the United States and other western countries (see, e.g. Lundgreen 1990; Belhoste and Chatzis 2007; Gispen 1990).

During the period of the *Ancien Régime* (*Old Order*) – primarily referring to the aristocratic, social and political system established in France from the fifteenth to the eighteenth century – and up to (and arguably beyond) the French Revolution, the word *ingénieur* was synonymous with a state engineer. France had become a centralised state with a strong public service. Various corps of state engineers attained an unrivalled position in French society: 'As engineers they lent *technical* expertise to non-juridical matters of public policy; as *state engineers* they rendered *administrative* services and represented true civil servants in the sense of *functionnaires*, while public lawyers lacked this degree of loyalty and ascendency' (Lundgreen 1990, p. 37). From its foundation in 1794, the *École Polytechnique* served as a preparatory school for all state corps. In addition to a solid underpinning in mathematics and science-based subjects, French state engineering graduates were tutored and oriented for careers as state administrators.

The establishment of the *École des Ponts et Chaussées* in France in 1747 may be considered the foundation platform for delivery of formal engineering education in Europe. As described in Bucciarelli et al. (2009), students enjoyed the privilege of being state employees whilst receiving a project-centric education under the tutelage of *savant* professors of the *corps*. The latter half of the eighteenth century saw the creation of further *écoles*, including the *École des Mines* (1783) and the *École de Travaux Public* (1794) – later retitled the *École Polytechnique*, with mission for provision of 'a high intellectual and scientific formation'. This was followed by the *École Centrale des Arts et Manufactures* (1829), offering a more industrial-based education.

The term *ingénieur* was also adopted in Germany in the nineteenth and twentieth centuries, with primary emphasis on military engineering careers. Although there were historical variations in development and orientation when compared to the French model, a similar trend arose through establishment of academies such as the Prussian *Bauakademie* in 1799, providing training for state engineers who served the state through projects and tasks including mining, public works and construction of public buildings and public enterprise projects (Lundgreen 1990).

Formalised engineering education in the United Kingdom had its origin with the establishment of the *Royal Engineering School* at Chatham in 1812. In the United States, the *Rensselaer School* in upstate New York opened in 1823. In Germany, the *Karlsruhe Polytechnische Schule* commenced student training in 1825. In Ireland the first Professor of Engineering was appointed in *Trinity College Dublin* in 1841.

In the early years of the twentieth century, as would be professionals, 'German engineers found themselves on the dividing line between the capitalist industry and the old order. With the exception of certain subgroups, engineers never fully succeeded in becoming fully part of either world and ended up being squeezed mercilessly between the two'. Gispen considers that the engineers' sociopolitical failure was related to Germany's industrial successes in the second half of the nineteenth century. 'The rift separating *Technik* from *Bildung* and *Besitz* became so deep in Germany that engineers were forced to develop something of a counterculture and compete rather than amalgamate with the dominant social order' (Gispen 1990, p. 2).

In his review of engineering education in Europe and the USA in the eighteenth and nineteenth centuries, Lundgreen's study on the emergence of 'school culture and the engineering profession' proffers that the latter part of the nineteenth century was a 'major divide in time' in the formation and identity of education across the western world. 'The rise to dominance of school culture in engineering education took place much later in England and the USA than in France or Germany' (Lundgreen 1990, p. 1).

The model of engineering education and early formation in England, Ireland and the USA had common traits but differed to those of France and by extension to Germany and other countries in continental Europe. The UK and Ireland developed no elite technical schools, but the education of engineers was taken up by the existing universities. Technical schools were opened towards the end of the nineteenth century, but these developed from the perspective of trades and craft – hands-on engineering – and were not intended to produce elite graduates to assume leadership roles. For example, in Ireland applied technological education commenced with the establishment in 1887 of *Kevin Street Technical School*, the founding nucleus of *Dublin Institute of Technology*. Broadly in Ireland, England and the United States, there was no corps of public lawyers nor of state engineers (apart from the military) existing which could have provided a role model for civil (meaning 'civilian') engineers, with no institutional provision for technical training of engineers in the eighteenth and nineteenth centuries. Nor was there institutional training for other professions; universities were essentially liberal arts colleges and schools of divinity. To become a lawyer or physician, with or without college education, one had to be apprenticed. However, professional societies, through a recruitment policy of cooption, provided and 'reinforced the network of relationships between pupils and masters'. Harvard and Yale were both established in 1847 as schools of applied science, however with greater focus on scientific education than technology. The Massachusetts Institute of Technology (MIT) was created in 1860 with a strategy based on a perceived need of a more technologically applied focused education to that offered by Harvard (Wickenden 1929).

It was only in the latter half of the nineteenth century that engineering education in the UK was underpinned by programmes in science and engineering through institutes of higher learning (Bucciarelli et al. 2009). Professional engineering bodies had also emerged as custodians of professional training and accreditation in engineering, for example, the Institution of Civil Engineers set examinations for qualification of membership to the institution. Coming forward to the mid-twentieth century, during the 1940s and 1950s, the Rensselaer School in New York subsequently developed along the lines of the polytechnic, in particular the *École Centrale des Arts de Manufactures* (Wickenden 1929). In this model it is interesting to note that students received tuition in the humanities in addition to their core engineering and scientific studies. Enhanced education in the humanities and social sciences in undergraduate engineering education was advanced with the release of the Grinter report on the *Evaluation of Engineering Education* (Grinter 1955). Grinter acknowledged that many engineers progressed into 'managerial and top executive positions in industry and government' and that the 'foundation should be laid for an understanding of human relationships, the principles of economics and government, and other fields upon which the engineering manager can build'.

The growth and spread of engineering professional organisations occurred in tandem with the establishment of engineering schools throughout the western world in the nineteenth and twentieth centuries and continues today. The Accreditation Board for Engineering and Technology (ABET) sets the standard and curriculum content for engineering and technology programmes in the USA. In the UK the Engineering Council is the coordinating body for a host of professional organisations with discipline specific mission. In Ireland, Engineers Ireland is the national institution with responsibility for advancement and accreditation of the engineering profession in Ireland. The *Washington Accord* (1989), *Dublin Accord* (2002) and *Sydney Accord* (2001) are international agreements among bodies responsible for accrediting engineering, technology and technician titles. Under the auspices of FEANI (*Fédération Européenne d'Associations Nationales d'Ingénieur*), the European Accredited Engineer label EUR-ACE was established in 2004 to facilitate accreditation and coordination of standards in engineering programmes throughout the European Union and beyond its boundaries.

Such organisations promote worldwide harmonisation and acceptance through professional recognition of engineering programmes, providing global networking and recognition of the engineering profession. In addition to core staff in the national organisations, volunteer chartered and professional engineers make significant contributions through engagement as committee members and as mentors and advisors to those seeking professional status. The institutions also offer a voice to the members of the profession at national level and on the international stage.

Engineering Leadership in Europe and the United States

In Ireland, England and the United States, the professionalisation of engineering and engineering education fostered a professional developmental channel that diverted engineers away from strictly technology management roles. As noted also by Tenner, 'at the turn of the 20th century, U.S. companies fearing manpower shortages resisted attempts to make elite postgraduate degrees the norm for engineers, as they were becoming for lawyers, doctors and executives' (Tenner 2005). Thus, for these countries, the lack of elite academies for engineering education, combined with industry pressures to ensure an adequate supply of engineers, contributed to the flow of engineers into industry and not into other leadership roles in Ireland, England and the United States.

It is also sometimes argued that engineers, by their education, are blinkered to examine only the technical problem before them and consequently do not see other contextual dimensions, such as societal dimensions, and so whilst they may have optimal solutions, they are only optimal with respect to the technical factors they take into account. In discussing the lack of engineers in political leadership roles within the United States, Tenner goes further than this and notes that one explanation may be that engineers 'self-select for social distance' and provides anecdotal examples in support of this theory. Interestingly, Tenner refers back to Veblen when he writes 'This is an old American stereotype…'. Veblen, championing what was later called technocracy, wrote that "the public considered engineers a somewhat fantastic brotherhood of overspecialized cranks, not to be trusted out of sight except under the restraining hand of safe and sane businessmen". He added, "Nor are the technicians themselves in the habit of taking a greatly different view of their own case" (Tenner 2005).

Whilst commenting in passing that a mix of talented people is ideally what is needed within the context of leadership, nonetheless in Ireland, England and the United States, the task should be to get sufficient numbers of engineers into roles wherein they can interact with and influence other decision-makers.[4]

[4] Given the collapse of the world economic system in the late 1920s, the argument can be made that had engineers been solely in charge of optimising industrial output, as argued for by Veblen, then engineers might well have made matters worse by increasing output into deflating national economies.

The Development of the Role of the Engineer in China

Let us return now to the question of whether China provides a supporting example for Veblen's thesis that engineers are best positioned to manage the material welfare of the community. Joel Andreas begins his brilliant study of modern leadership in China with the simple statement that 'China today is ruled by Red engineers' (Andreas 2009, p. 1). This runs counter to the Marxist vision of a classless society, despite the fact that the Chinese Communist Party (CCP) adopted a Marxist version of socialism. According to Andreas, the CCP was founded by intellectuals, but during two decades of armed insurrection, it became a party of peasants, which resulted in a rise in peasant leadership. During the early years of communist control in China after the 1949 Revolution, collectivisation eliminated private ownership of land and the state took control of large enterprises, with small enterprises being combined into cooperatives.

Whilst it is beyond the scope of this chapter to examine the *Great Leap Forward* from 1958 to 1961 and the subsequent *Cultural Revolution* from 1966 to 1976, what is important to our work is that it was the subsequent reaction to the *Cultural Revolution* that resulted in the creation of a new dominant class led by engineers. Andreas makes the observation that 'Mao was completely unsympathetic with intellectuals' conviction that their expertise made them more fit to run the country than the communists'. But with Deng Xiaoping's return to power after the death of Mao Zedong, it was those people who were educated at elite technical universities and there received their technical and political training who began moving into positions of power (Andreas 2009). It was at these elite technical universities that they became both *Red* (political training) and *Expert* (studying engineering as an educational discipline). To understand the rise of engineers to dominant leadership positions, it is therefore necessary to understand what it meant to be both *Red* and *Expert*.

Consider first the Chinese Communist Party. Founded in 1921, the Chinese Communist Party (CCP) is the ruling political party of the People's Republic of China (PRC). The CCP maintains a unitary government centralising the state, military and media. The legal power of the Communist Party is guaranteed by the PRC constitution. The CCP is the world's largest political party, claiming nearly 78 million members at the end of 2009 which constitutes about 5.6 % of the total population of China. The CCP is a strongly hierarchical organisation. From the age of nine, children can join the Young Pioneers which is run by the Communist Youth League. At age 15, young people can join the Youth League. The Youth League, in turn, is run by the CCP, and people can join the CCP at age 18. According to Andreas, this is an increasingly selective hierarchy with more intense competition to gain membership of the Youth League and then the CCP itself.[5]

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[5] The primary organisation of power in the CCP comprises the Central Committee which includes (a) the Politburo Standing Committee, which currently consists of nine members; (b) the Politburo, consisting of 24 full members (including the members of the Politburo Standing Committee) and one alternate; (c) the Secretariat, the principal administrative mechanism of the CCP, headed by the

Likewise, the Chinese education system was hierarchical and selective. In its first decade of power, the CCP reorganised the school system making it increasingly more difficult to progress from primary school to junior middle school, hence to senior middle school and then on to college. This created tremendous competition among students for increasingly limited numbers of places as they progressed through the education system.

In order to support a programme of rapid industrialisation, higher education was reorganised along a Soviet model with colleges assigned a specialised teaching mission aligned to a narrow range of disciplines. This facilitated a system to produce large numbers of highly specialised engineers. According to Andreas, between 1947 and 1965 the number of Chinese university students grew by a factor of five (from 130,715 to 644,885) whilst the number of engineering students grew by a factor of 12 (from 23,035 to 292,680). During the *Great Leap Forward* (1958–1961), the Chinese also adapted the Soviet educational model to combine specialised teaching with research and production as elements of the university education, which was retained after the failure of the *Great Leap Forward*. Universities such as Tsinghua continued to stress the importance of hands-on learning and ensured that its students learned technique rather than simply engaging in manual labour as part of the curriculum.

The CCP 'created a highly centralized, hierarchical and meritocratic education system' whilst at the same time it was 'resolutely committed to eliminating class differences based on education'. This paradox caused difficulties in the period between the 1949 Revolution and the Cultural Revolution in 1966. The CCP used slogans such as *politics takes command* to argue that experts should be subordinated to political leaders. But the reality was that 'poorly educated Communist officials were attempting to supervise non-Communist experts' so that despite having authority they lacked technical understanding to provide leadership. Whilst at a micro-level we can characterise this in a Veblen-style argument that experts were being managed by nonexperts, at a macro-level the *Great Leap Forward* was a disaster for China as the attempted expansion of its industrialisation failed and millions starved to death.

To address this problem the CCP realised that the 'long-term solution was to train a new generation of cadres who had expertise and were also committed Communists, that is, cadres who were both Red and expert' (Andreas 2009, p. 50). As recounted by Andreas, in 1958 the President of Tsinghua University, Jiang Nanxiang, addressed the collected students and teachers of the university and said: 'Our requirement for training cadres is that they become both Red and expert. If you are not thoroughly Red and deeply expert, that is a huge waste'. Seven years

General Secretary of the Communist Party of China; and (d) the Central Military Commission (a parallel organisation of the government institution of the same name). The Central Committee has approximately 370 members, including ministers and senior officials in Beijing and leaders of provincial governments and cities in addition to senior military personnel. The current membership of the Politburo Standing Committee includes Hu Jintao, President of the Peoples Republic of China and Chairman of the PRC Central Military Commission, and eight senior party members.

later in 1965, Jiang addressed the incoming students to Tsinghua and told them that in the future China would be run by engineers and that since Tsinghua was the leading engineering school in China, it was likely that some of these incoming students would become national leaders. Later in 1978, after Deng Xiaoping came to power, Jiang was appointed Minister for Higher Education. Finally in 1980, Deng himself addressed the assembled body of Tsinghua University and declared that ‘expertise does not equal Redness, but Reds must be experts’. This spelled the end of the class-levelling aspects of Mao’s policies and established a new class who held both Red and Expert credentials and who were rapidly promoted into leadership positions. A significant feature of the CCP’s Politburo Standing Committee today is that eight of the nine elected senior officials trained as engineers. This contrasts with the largely legal profession political leadership in both Europe and the USA.

The result of the political and educational structures established was that CCP members who were students in elite technical universities had come successfully through two separate, distinct and rigorous selection processes: one to gain membership of the CCP and one to become a student at an elite technical university. Andreas also notes that job assignments for graduates corresponded with the rank of the university, and so graduates from top-ranked universities such as Tsinghua University in Beijing ‘received prized assignments in national and provincial government offices, industrial ministries, large industrial enterprises, research institutes and universities’. This of course was possible because of the collectivisation policies implemented after the revolution in 1949 allowing the government to place whomever it wanted wherever it wanted across the industrial sphere. From the perspective of Veblen, this is a centralised version of the engineers in control that he advocated. Therefore, these graduates had the additional characteristic of post-university roles that provided them with considerable responsibility and experience. It is interesting to note here the strong parallels with the ‘selection, streaming and differentiated experience’ discussed at length by Gladwell in his popular book *Outliers* to explain those people who become successful in sports and which Gladwell uses to set the framework for success in other human endeavours (Gladwell 2008).

A transformation in ideological thinking occurred in the post-Mao period as a logical consequence of accepting the requirements to be both Red and Expert. During the Mao era, party leaders were not university educated, but instead came from the ranks of the masses. Post-Mao, *Red and Expert* meant that engineers were now considered to have the best qualifications to be administrative and political leaders and this has naturally resulted in people educated as engineers discharging nonengineering roles.

In addition to coming successfully through the two separate rigorous selection processes of education and CCP membership, followed by prized government roles for graduates, these graduates also benefitted from maintaining a network of fellow graduates from elite Chinese universities. This is particularly true of Tsinghua University. As Li notes, ‘Indeed, there is no more telling example of the role of a school network in the rise of technocratic elites in post-Mao China than in this institution’ (Li 1994, p. 2).

A further significant advantage enjoyed by CCP members who graduated in engineering from elite universities was the school networks they developed and maintained. Writing in 1994 Li noted the importance of political networks developed at Tsinghua University: 'Some China experts believe that technocratic elites lack close interpersonal ties or political networks, and that technocrats come to power mainly because of their technical expertise. Yet a careful analysis of the biographical backgrounds of Qinghua technocrats shows that their political networks at Qinghua are more important than technical expertise for explaining their success in acquiring leadership posts' (Li 1994, p. 2). In echoing what has been said of elite schools in other countries such as Harvard or Yale, Li states that 'belonging to an elite school network is far more essential for politicians than having an elite university degree. Intelligence and skills facilitate career advancement, but connections, or *guanxi*, are what really count' (*ibid*, p. 2–3).

Conclusion

This chapter began with a brief comparison of the relative position of two very different economies, those of Ireland and China in 2011. We asked the hypothetical question: *What if Ireland had been lead by engineers, would it have avoided the difficulties it now faces*? To provide a framework to examine the role of engineering leadership, we took as our starting point the arguments developed by Thorstein Veblen that engineers were ideally positioned to assume and assert greater control over the mechanisms of production. However, Veblen wrote in 1921 just after the Great War, and this turned out to be a critically important period in global economic development. For what occurred in the 1920s – and has subsequently been characterised as the period between the two world wars – was an economic collapse on a global scale. This collapse fundamentally reshaped the remainder of the twentieth century, including the possibility of an enhanced role for engineers in leadership roles.

We have seen that a system evolved in Ireland in which there are no elite engineering academies and no mechanisms to ensure a steady stream of highly qualified engineers into key leadership and influencing positions.[6] This contrasts

[6] There are exceptions to the rule. Looking back over several decades at deputy and ministerial posts in the Irish Parliament, there is perhaps only one entry of a senior ministerial post held by an internationally renowned engineering academic. Tribute was paid by UNESCO-IHE Institute for Water Education in August 2008 upon the death of Professor James Clement Dooge.

Professor Dooge (1992–2010) was an Irish hydrologist, politician, engineer and academic. He lived a multifaceted existence with his roles including a period as Irish Minister for Foreign Affairs, Chairman of the Irish Senate, President of the International Council for Science, President of the International Association of Hydrological Sciences and Professor of Hydrology at Dublin University. He had a significant role in the development of the European Union during the Irish presidency of 1984 (UNESCO-IHE).

directly with China wherein the CCP-afforded status to engineers and scientists and the combination of membership in the CCP, access to elite engineering universities, key government roles after graduation and the support of old school networks all combined to ensure that engineers dominate political and industrial leadership in modern China.

However, there is a critical point to be made with regard to China and its development and which links back to the framework for this chapter. First, other eastern European communist states adopted a technocratic leadership regime. To achieve this they restructured their higher education system into specialised schools. What China did differently is that it reacted against Mao and the Great Leap Forward, which attempted to make experts (i.e. engineers) subservient to Reds (i.e. political party cadres). When the Great Leap Forward failed leaving millions of people dead, China moved to implement a meritocracy combined with a technocratic, centrally controlled party leadership regime. It was the meritocracy combined with the highly competitive and highly selective system that ensured that only those people who were capable of getting through the rigorous party selection process and succeeding in the leading engineering universities such as Tsinghua University ended up in key government-designated jobs.

Perhaps Cheng Li (1994) captures the point best and links it back to Veblen as follows. 'In the classic writings on technocracy, technocrats are usually portrayed as people who are interested not in power but in technical matters. They are selected not because of their political associations but because of their technical expertise. China's experience is different'. Li goes on to argue that 'The selection of Chinese technocrats, therefore, is not based on criteria which are universalistic, scientific-technical, or impersonal, but is conditioned by the political and institutional network through which they have been promoted. China is entering a new era in its century-long modernization process. A new generation of leadership, a technocratic elite, is moving toward the centre stage of Chinese politics' (Li 1994).

What China appears to have proved was that a Marxist classless society could not succeed if that society wished to be a successful industrialised nation. The reason is that technocrats must be capable of exercising the skills that they have developed through their education and be empowered to manage those without such skills. Mao saw the experts as a class of intellectuals – and he fought hard to suppress them and ensure that the CCP was not controlled by them and indeed that uneducated peasant cadres were in charge of production. This is Veblen again, but from a different perspective. Veblen argued that it was the one-eyed 'captains of industry' to blame and then the investment bankers. But substitute 'nonexpert party cadres' for captains of industry and Veblen's argument is made from a Chinese perspective. Therefore, it is in modern China that we find evidence of Veblen's central argument.

The situations in each country are unique to that country, and it would be unwise to draw generalisations from their individual circumstances. For example, in China the authoritarian, single party system was a necessary ingredient because it ensured that the system was implemented and collectivisation ensured that the engineering graduates received important industry and government jobs. This worked in China and for China at a particular point in its history, but even now it is changing as more nonengineers move into positions of power, and the privatisation of assets continues in China. But if one were to generalise, a hybrid environment blending meritocracy with technocratic leadership moderated by nonengineering influences might well be the recipe for a successful country.

One question that remains as we close this chapter: are there parallels between the shift in economic power from the United Kingdom to the United States at the end of the nineteenth century to the shift in economic power from the United States to China at the start of the twenty-first century? Further, given the current global economic difficulties which exist, particularly in the United States and Euro-zone countries, are there parallels with the Great Depression of 1929–1933?

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Chapter 22
Harmonization with Nature: Ancient Chinese Views and Technological Development

Guoyu Wang and Yuan Zhu

Abstract Contrary to the emphasis on the control of nature in the Western view of technological development, the Chinese view of technological development aims at abiding by the laws of nature and maintaining harmony with nature. Harmony is hereby the direction of development, the moral principles and methodological norms of development, as well as the assurance of development.

Keywords Harmony • Nature • Technological development • Unity between man and nature

Introduction

The Chinese expression *fazhan* for "development" in English consists of two words: *fa* and *zhan*. *Fa* denotes taking place or sending out, often indicating changes from nothing to something; *zhan* denotes spreading or expanding, often indicating changes from small scales to large scales. When combined as *fazhan*, they mean changes from being small to large, weak to strong, and simple to complex.

Contrary to the emphasis on the control of nature in the Western view of technological development, the Chinese view of technological development aims at abiding by the laws of nature and maintaining harmony with nature. Harmony is thereby the direction of development, the moral principles and methodological norms of development, as well as the assurance of development. The harmony

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between man and nature (nature is referred to as *tian* in Chinese, literally meaning sky) can ensure abundant harvests, the harmony among humans themselves can guarantee peace and prosperity, and the harmony within human bodies and souls can safeguard health and promote longevity.

The focus of this chapter is on the ancient Chinese harmony-oriented view of technological development. The first part introduces the ancient Chinese view of harmony between man and nature, emphasizing the thought of "unity between man and nature," which is the basis and prerequisite to understanding the Chinese view of technological development. The second part takes the thought of harmony as key element from the ancient Chinese classics such as *The Spring and Autumn of Lü Buwei* (吕氏春秋 Lü Shi Chun Qiu), *The Writings of Prince Huainan* (淮南子 Huai Nan Zi), *Book of Diverse Crafts* (考工记 Kao Gong Ji), and *The Orthodox Classic of Huangdi* (黄帝内经 Huang Di Nei Jing) and analyzes the philosophy of harmony between man and nature for its manifestation in the technological development of agriculture, handicraft industry, and medicine. The last part reemphasizes the differences between the ancient Chinese view of harmony between man and nature in terms of their attitudes to the natural world and technological development and the Western view of technological development and meanwhile affirms the significance of such a view in constructing the strategies for the development of new technologies.

The Relationship Between Man and Nature Based on Harmony

Harmony in the Chinese Context: The Differences and Similarities in the Concept of Harmony Between the Chinese and Westerners

Harmony is one of the most ancient concepts in the history of philosophy, sharing as well a common heritage in the history of Eastern and Western thoughts. In both ancient China and ancient Greece where Western philosophy largely originated, philosophers and thinkers have laid much stress on this concept.

In the West, the English word "harmony" and the German word "harmonie" are derived from the Greek word "άρμονία" or "άρμοττω," which originally means to combine and connect. It is not simply a combination or connection; it involves seeking concordance with the laws of the universe using the best possible means and models and has three indications: (1) the whole composed of parts, (2) the structure formed according to certain rules, and (3) the function utilizing the structure to its fullest potential.

The earliest concept of harmony from an ontological point of view of the universe was expounded by the Greek philosopher Pythagoras and his disciples (Schavernoch 1981). In Pythagoras's view, the composition and movement of the universe follow certain proportions and rules which are determined by numbers by which all in the universe are regulated and lead to harmony. As a result, harmony means the harmony between and of numbers. Plato inherited this thought. In *The Republic* and some other works, Plato repeatedly talked about the concept of harmony. In his opinion, like the harmonious and concordant tune composed of different notes in music, to achieve harmony is to arrange, group, and reconstruct different things according to certain rules and order (Plato 1985). In the modern history of Western philosophy, the German philosopher Leibniz inherited Pythagoras's thoughts on harmony and systematically elaborated on those thoughts. Targeting Descartes's passive mechanical thoughts of the separation between body and soul in which the body is regarded as soulless, Leibniz proposed the concept of harmony. In Leibniz's view, the monad is the most basic entity, of which the universe is composed. Monad means unity and unit. In his view, monad does not only dwell in the form of unity in variety but is also the power of its own movement, that is, monad is not passive but active, and it is the unity in variety of the life force. Due to the fact that the unique feature and property of every monad concerns all monads, that is, they concern the whole universe of entities, the universe is formed as a whole, which is no longer the unity of a single monad, but the whole of the congregation. The supreme state of such wholeness is harmony, including the harmony between different monads and the harmony between an individual monad and the whole universe. In short, Leibniz's harmonious universe is ultimately based on God's "predestination" because God creates the world according to the maximum of harmony and beauty (Poser 2002, pp. 54–62).

As is seen from the above, both Pythagoras and Leibniz expound harmony from an ontological and structural point of view. Harmony first manifests itself as order and indicates the structural state of the regular unity between one and many, and it aims at wholeness and perfection. If human conduct and society are arranged according to such order, happiness and justice can be realized.

Similarities and essential differences coexist in the concepts of harmony between the Chinese tradition of philosophy and the Western history of philosophy. What they share is that harmony is the internal unity between one and many, and yet the Chinese view maintains that this unity is not predetermined and uniform, but dynamic and specific, in a process of constant generation and renewal.

According to Xu Shen's *Origin of Chinese Characters* (Xu 2007) from the Han Dynasty, "咊" (the original ancient Chinese character for 和 *he* meaning harmony) means to reply. Its left part indicates some oral action of the Chinese character 口*kou,* and its right parts indicate the pronunciation as the same as the Chinese character 禾*he*. So originally as a verb, it means to reply or respond orally, which can be exemplified in the following lines: "When the crane sings in the mountain shade, its fellows respond accordingly" (Huang Shouqi and Zhang Shanwen 1989, p. 489); "The bamboo flute keeps harmony with singing" (Xiao Tong 1977); and "To tune with the pentatonic notes" (Zhang Yuling 2008, p. 232). The character 和 *he* was also shaped as 龢and 龤 in ancient China. 龢 follows 龠 on its left part, which as an ideograph means a bamboo musical instrument, similar to today's vertical bamboo flute (Dong Xiao Fu). 龤 also existed in the Chinese classics over 2,000 years ago. In *The*

Origin of Chinese Characters, 龤 equals the modern word偕 meaning harmony: "龤: harmony in music, following龠 on its left side and pronounced as 皆 on its right side." As a result, the original meanings of 和 and 谐 are both connected with music. In ancient China, different musical scales are marked as five notes of 宫 *gong*, 商 *shang*, 角 *jiao*, 徵 *zhi*, and 羽 *yu*. To keep in tune with the five notes means 和 *he* harmony. As can be seen from *The Writings of Prince Huainan*, "*zhi* derives from *gong*, *gong* from *shang*, *shang* from *yu*, *yu* from *jiao*, *jiao* from 姑洗 *guxian* (the fifth of the ancient Chinese standard of twelve-tone), and *guxian* from 应钟 *yingzhong* (the twelfth of the twelve-tone), and yet *yingzhong* does not fit the five-tone standard and therefore is named harmony which adjusts the balance with *gong* in the five-tone standard" (Liu Kangde 2001, p.125). This connotation of *he* is later extended to mean the harmony and unity between different people and things. For example, "Poetry articulates our intentions; song prolongs those words into chants; notes follow the chants, and they are put into harmony with the scales. When the eight instruments are in accord and do not encroach upon one another, then the spirits and men will be brought into harmony" (Wang Fuzhi 1976, p. 15). "In eight years, we gathered among the different states for nine times, and like the harmony in music, we had nothing out of concord" (Xiang Gong Shi Yi Nian 2006, p.173). As can be seen from the above examples, harmony does not mean the unity without differences and principles. On the contrary, harmony exists with differences as its premise. In Confucius's view, an honorable man is the one who insists on harmony based on differences and principles, while a mean man is the one who sticks to no principles, agrees blindly, and only caters for favors ("an honorable man can maintain harmony without agreement while a mean man can agree without harmony") ("Zi Lu" 1984, p. 2002). A dialogue between king and minister in *Zuo Zhuan* vividly illustrates the difference between the concepts of harmony (*he*) and agreement (*tong*) and explains the idea of harmony as the unity in varieties: "To keep harmony is like making meat or fish soup with water, fire, vinegar, sauce, salt and plum, and with firewood cooking it. The chef balances the taste and makes it moderate, adding sauce when the taste is not enough and reducing sauce when it is excessive" (Li Xueqin 1999, p.1400).

Harmony is not only the unity of differences but also the unity based on opposites. It is this unity based on opposites and contradictions that makes harmony the basis and power for the generation and development of all in the universe.

In the ancient Chinese tradition of philosophy, *yin* and *yang* are considered as the origin of all in the universe. Thus, *yin* and *yang* can be considered as two different kinds of substance as well as two different kinds of power. Laozi said: "Tao gave birth to the One; the One gave birth successively to the Two, the Two to the Three and the Three to the Ten Thousand. The Ten Thousand embrace both *yin* and *yang* and therefore blend all breaths into harmony" (Laozi 1984, p . 232). In Zhuangzi's view, it is no less than the clash and integration of the two opposites of *yin* and *yang* that generate everything in the universe, which is stated as "the two meeting and integrating in harmony and therefore generating everything" (Tian Zifang and Chen Guying 1983, p. 539). Obviously, harmony is the driving force for the movement and change of everything; "everything coexists in harmony and therefore develops its full potential" (Xunzi 1979, p. 270). So "only in balance and harmony can the sky and earth find their own positions and everything generates life" (Zhu Xi 1983, p. 18). Later in the Confucian school of philosophy in the Song and Ming dynasties, the concept of *yin* and *yang* was elevated to the sphere of metaphysics. Zhang Zai said: "Nature keeps itself in perfect harmony and balance. The music of harmony is the origin of Tao!" (Wang Fuzhi 1975, pp.110, 116). "The two sides of *yin* and *yang* in constant cycle establish the core values of the world" (Wang Fuzhi 1975, p. 23).

As harmony is the premise and driving force for the generation of development of everything, it naturally becomes the ideal goal of human pursuit from the family of "harmony ensuring prosperity" to the state of "harmony protecting security, justice, welfare, abundance, and peace" (Huang Shouqi and Zhang Shanwen 1989, p.6). However, harmony does not only manifest itself as a state of perfection but also a process of achieving perfection. The Chinese word "和*he*" can also be pronounced as "和*he*" in the fourth tone as a verb to mean participate, respond, or harmonize, where it becomes the method and approach to achieve the ideal state of perfection, which is stated as "balance is the basis of the world; harmony is the Tao to the world" (Zhu Xi 1983, p.18), explicitly pointing out the methodological significance of harmony as the Tao.

The Harmony-Based Holistic View of Nature: "Harmony Between Nature and Man"

Harmony is the core concept in Chinese culture, as well as the common basis of Confucian and Taoist philosophies. It is the principle and methodological basis for the relationships between man and nature, between man and society, and between one and the other. "Harmony between nature and man" ("*tian ren he yi*") is the manifestation to reflect the harmonious relationship between nature and man in ancient China. In this Chinese idiom, "*tian*" (originally means sky) refers to nature in the modern sense, and it also refers to the supreme will, the Tao, the law, or the principle which dominates human beings (Feng Youlan). On the one hand, "*tian ren he yi*" refers to the unity and integration between man and nature, reflecting the unitary view of nature; on the other hand, it refers to the essential mutual correspondence between the Tao of nature and that of man, the laws of nature and the ethics of human relations, and therefore the Tao of man must be in accordance with that of nature. Human conduct must be in accordance with the laws of nature, acclimatizing oneself to nature. As a result, "*tian ren he yi*" contains the methodological significance of instruction.

The Natural Environment Is Unitary and Man Is Only Part of the Whole

Etymologically, "天"(*tian* literally means sky) is formed as "" in the oracle bone inscriptions and "" in the inscriptions on ancient bronze objects. The image is of above the top of a man. In Xu Shen's *Origin*, the definition is "天*tian*: top, that above the top of a man" (Han Dian). It refers to something above man, indicating supremacy. In Yu Wujin's analysis of the origin and formation of the character, "the etymology reveals the fact that the true relationship between nature天 *tian* and man 人 *ren* is as follows: man is within nature, and nature is fulfilled by man"; in addition, "in Chinese, man has always been part of Nature" (Yu Wujin 2009, p. 45). In other words, contrary to the Western culture and tradition in which the relationship between man and nature (Zhuangzi, p. 471) is often regarded as that between subject and object, in the Chinese culture and tradition, nature is the ultimate source of everything, man is born from nature ("nature is the originator of everything" (Dong Zhongshu 1989, p.85) or "nature is the beginning of man") (Si Maqian 2005, p. 1933), and the relationship between man and nature is that between part and whole.

Both Nature and Man Must Obey the Laws of the Universe

In Taoism, the Tao is the ultimate source of everything, the supreme entity of the universe, and yet nature refers to everything in the universe (Feng Youlan 2006, pp. 90–91). Nature, man, and everything are all the products of the Tao; man is not above the values of other living beings in the natural environment; and man shares equality with everything in the natural environment, as is stated: "I was born with nature, and everything and I become the oneness" (Chen Guying 1983, p. 71). In the whole composed of man and everything, man like the rock and trees receives the same vital energy 气 *qi* of *yin* and *yang* from nature ("I exist in nature, affected by *yin* and *yang*; in nature I am like a piece of small rock or wood in the big mountains") (Chen Guying 1983, p. 411); on earth man like plants, birds, and animals only occupies one spot ("There are ten thousand numerous things in nature and yet I am only one of them; human beings congregate on earth where crops grow and vehicles pass, and yet a human being is only one of the mass. Compared with the ten thousand, a human being is only like a tiny piece of hair on the whole body of a horse") (Chen Guying 1983, p. 411). Therefore, the relationship between man and nature, from the Taoist point of view, is only that of "man obeying the law of the earth, earth obeying the law of the sky, the sky obeying the law of the Tao, and the Tao following its own nature."

The Essential Correspondence Between Nature and Man, The Unity Between the Law of Nature and that of Man with the Latter According with the Former

In comparison with the Taoist idea of "the unity between nature and man" that "man must control his own conduct without violating the law of nature" (Zhang Shiying 2007), the Confucian idea emphasizes the naturalistic basis for the ethical principles of "benevolence, righteousness, courtesy, wisdom, and sincerity." It is believed that ethical principles must accord with the law of nature. *The Book of Changes* says,

> As for the superior person, his virtue accords with the sky and earth, his brightness with the sun and moon, his penalty with ghosts and gods, when his action takes place before nature, nature will not betray him, and when his action takes place after nature, it accords with the cycle of nature. Even nature will not betray him, neither will human beings.

Confucius believes that such natural feelings as filial piety are the "basis of benevolence" ("Xue'er," *The Analects*). In the idea of the "benevolent human nature," Mencius explicitly attributes the origin of "benevolence, righteousness, courtesy and wisdom" to human nature, naming them as the "four aspects": "to feel pity is benevolence, to hate evil is righteousness, to show respect is courtesy, and to distinguish between right and wrong is wisdom." All these are basic human qualities endowed by nature, and therefore, Mencius says "If you fully explore your mind, you will know your disposition. If you know your own disposition, you will know nature." It is also said in "The Doctrine of the Mean" of *The Book of Rites* that "sincerity is the law of nature, and the practice of sincerity is the law of man." It is believed that as long as man promotes the virtue of "sincerity," there will be accordance between man and nature. Dong Zhongshu from Han Dynasty explicitly proposes "the relationship between nature and man must be unified as the oneness" (Dong Zhongshu 1989, p. 60). Obviously nature can interact with man. Man's conduct must follow the law of nature; otherwise, he will be punished by nature. Later in the Confucian school of philosophy in the Song and Ming dynasties, the idea of the "unity between nature and man" reached the summit. In his work *Zhengmeng: Chengming*, Zhang Zai clearly proposes the concept of the "unity between nature and man." He says: "A true scholar reaches sincerity due to his clear-sightedness, and reaches clear sightedness due to his sincerity, and therefore nature and man are united as the oneness." "Sincerity" refers to the law of nature, and nature has certain rules; "sincerity" is also the realm of the saints whose conducts accord with the principles, affirming the substantiality of the real world, which makes it possible for the "clear-sightedness." Zhang Zai believes that by sincerity and clear-sightedness, one affirms the oneness between the law of nature and that of man, that is, "whatever is sincere and clear-sighted reveals the indistinctiveness between the law of nature and that of man" (Wang Fuzhi 1975, p. 94). The ethical principles and the law of nature are in accordance, and both man and nature follow certain unified rules. Thus, the "unity between nature and man" has eventually evolved into a philosophical proposition.

Harmony and Technological Development in Ancient China

In fact, harmony and the "unity between nature and man" are no longer philosophical concepts alone, but they have become a part of the Chinese culture and immersed in Chinese thinking and conduct, significantly affecting the development of ancient Chinese technology. As Tang Junyi said: "The unity between nature and man is the central concept in Chinese philosophy – which has directly governed the development of Chinese philosophy and indirectly governed all the Chinese social, political and cultural ideals – and therefore it has been very prevalent in Chinese philosophy" (Tang Junyi 1978, p. 111). Even though Xunzi tries to "clearly distinguish between nature and man," his focus is only on the respective role each plays and on the duties man must stick to. Even his idea of "controlling nature for man's use" is contrary to the Western technological view of regarding nature as the target for human understanding, exploitation, reconstruction, and control and particularly for reconstructing nature. Instead, he places man and nature within the whole framework of harmonious unity and, on the premise of working with nature, proposes to make use of the materials and rules to serve human needs. "Seldom did he isolate man from nature for his observation" (Qu Xiuquan 2010, pp. 94–97). Consequently, on the one hand, he calls for revering nature and respecting natural laws instead of treating nature as the opposite; on the other hand, he proposes some regulatory framework and principles for human conduct: human conduct must not trespass the boundary of nature – which at the same time becomes the principles and the methodological rules for technological development, forcing the technological development to follow the natural laws and constantly to adjust itself to the changes of nature, from which originated and developed certain sets of technological strategies to keep pace with the time, to consider the actual situation, and to adjust measures to specific conditions.

Harmony Reflected in the Development of Agricultural Technology

The idea of harmony with nature in ancient China is first reflected in the agricultural production activities. As is well known, China is an agricultural country. The reliance on nature in agricultural production provides the basis of experience for forming the philosophical thought of acclimating nature, and in addition, working with nature also becomes the basic directional thought for agricultural production practices. The ancient classics such as *Spring and Autumn of Lü Buwei* and *The Writings of Prince Huainan* are the typical examples. *Spring and Autumn of Lü Buwei* was written in the Warring States Period. The book is based on the synthesis of the various kinds of thoughts and farming experience in the pre-Qin period, according to the four seasons, the division of the 12 months of the year and the cycle of phenology, with the four seasons and 12 months as the key link and the cycle of the *yin* and *yang* as the latitude and longitude, and with the "birth in spring, growth in summer, harvest in autumn and storage in winter" as the clues, combining celestial phenomena, phenology, *yin* and *yang wuxing* and *wufang*, husbandry, laws and rules, and personal affairs. It proposes a whole set of strategies for agricultural development based on the harmony between man and nature.

Farm According to the Season and Never Violate the Farming Season

How to maintain harmony with nature in the agricultural production? The Chinese ancient farmers and agriculturalists summed up a series of strategies from their practice, among which the first and foremost is to farm according to the season and never violate the farming season. In their view, to farm, one must first follow the season and follow nature, that is, "to farm according to the season" (Zhang Yuling 2008, p. 206). The right "season" should be considered as the priority. It was believed that "the principle in farming is to observe the season: the felling in the wrong season will either break or bend the logs; the delay for harvesting crops will end in natural calamity, for although it is human beings that do the farming, 'the earth breeds everything' and the heaven nourishes everything" (Zhang Yuling 2008, p. 273), and "when spring comes, plants start to grow, and when autumn comes, plants start to wither" (Zhang Yuling 2008, p. 116). As a result, when grains are planted in the right season, the stems will be longer, the seeds will be full and taste good; otherwise, when they are planted in the wrong season, either earlier or later, the seeds will neither be full nor taste good (Zhang Yuling 2008, p. 273). Therefore, one must plant and harvest in the right season and give the land its due rest. One must observe the prohibitions in the four seasons such as "no felling in the wrong season, no mowing and burning in the swampland, taking no traps and nets for catching birds or animals outdoors, no fishing nets in the waters, and no boating without official permit." If one farms without violating the right season, "there will be plenty of grain and fish for food and plenty of wood for dispensation." (Li Xueqin 1999, p. 10).

Farm Efficiently According to the Specific Conditions

To be in accord with nature and maintain harmony with nature does not only include farming in the right season but also involves farming allowing for specific geographical conditions and adopting different strategies on different lands. This is especially important for agriculture which relies on the land for its development. Under such circumstances, the concept of the appropriate land use and farming started to develop. "The appropriate land first refers to growing different crops according to different conditions of the soil. For example, in *Dasitu*, soil is classified into twelve types, whose features are further clarified in terms of their differences and their appropriateness for growing different crops" (Dong Kaichen and Fan Chuyu 2000, p. 112). *The Writings of Prince Huainan* mentions the soils in different regions, already concerning soil classification. "One must plant crops in the appropriate soil; otherwise, they do not grow" (Dong Kaichen and Fan Chuyu 2000, p. 271). The article "Rendi" proposes different farming methods according to different features of soil: "Hard soil must be softened, soft soil must be hardened, idle soil must be more frequently cultivated, more frequently cultivated soil must be made idle, poor soil must be enriched, rich soil must be made lean, and dry soil must be made moist. Crops must not be planted on the ribbing in the high field, and neither must crops be planted in the furrow in the low field."

Fan Sheng Zhi Shu, an important book in agronomy in late Western Han Dynasty, is usually considered as the earliest book in agronomy in ancient China. It explicitly states: "The basis for good farming is to be punctual in time, harmonious in soil, rich in manure, and diligent in cultivation" (Dong Kaichen and Fan Chuyu 2000, p. 203). "To be harmonious in soil" refers to meeting the demand of "harmony" in soil by cultivation. "Harmony" represents the ideal state of the general conditions of the soil, including the balance between softness and hardness and richness and aridness. The book also includes some ideas of "cultivating and harmonizing the soil," "balancing and harmonizing the field," "harmonizing and softening" the field and soil, and "harmonious soil" or "unharmonious soil" (Fan Shengzhi 1959). These ideas demonstrate the deep-rooted concept of maintaining harmony with nature developed by the ancient Chinese from their technological practices.

The Harmony Among the "Three Elements" of Heaven, Earth, and Man

The harmony between nature and the technological development of agriculture is based on acclimatizing to nature and adjusting to the land, which inevitably involves man, as is said: "Man does ploughing and sowing, earth does breeding and heaven does growing" (Zhang Yuling 2008, pp. 206, 273). Thus, the universe is composed of the three elements of heaven, earth, and man; the harmony among heaven, earth, and man makes possible the technological development. In the theoretical system of the "three elements," man parallels with heaven and earth, who is neither the slave of nature nor is the conqueror, but a participator in the whole natural process. This view is very different from the Western view of nature and technology in that the Western view places man as the observer of nature. As a result, man and nature are in a state of confrontation, but not of balance and harmony. Essentially, the theory of the "three elements" unifies the different elements of sowing, heaven, earth, and man, and directs the development of agricultural technology in the integrated, interrelated, and dynamic concept.

Harmony Reflected in the Technology of Handicrafts

Similar to the emphasis on the harmony among heaven, earth, and man in agricultural development, the technology of handicrafts in ancient China follows the same principle. The encyclopedias of handicrafts in ancient China such as *Book of Diverse Crafts* (*Kao Gong Ji*) and *Exploration of the Works of Nature* (*Tian Gong Kai Wu*) provide us with detailed explanations.

Book of Diverse Crafts (*Kao Gong Ji*) is the literature recording the various norms and manufacturing techniques for the official production of handicrafts in the Spring Autumn period (corresponding to the first half of the Zhōu Dynasty), and it is the earliest monograph of handicraft techniques in China. The book takes an account of six categories of handicraft making such as carpentry, metalworking, leatherworking, dyeing, jadesmithing, and pottery making including 30 subcategories, 6 of which were already lost and 1 more of which was added, and thus only 25 subcategories remained. These 25 subcategories involve the knowledge and experience in mathematics, mechanics, acoustics, metallurgy, architecture, etc. The book, well known as the encyclopedia of handicrafts in seventeenth-century China, not only is the most detailed and authoritative technological work but also includes rich thoughts on philosophy and technology. The book not only shows the advanced handicraft techniques that existed in ancient China but also reveals the important genesis of technological development.

Harmony Between the "Works of Nature" and "Works of Man"

In the oracle bone inscriptions, the Chinese character "工*gong*" for "works" in English takes the image of a carpenter's square. In Xu Shen's *Origin*, "*gong*" means "well crafted, like a man holding a ruler" (Han Dian). According to Yang Shuda's annotation, "*gong* means an instrument, so a man can hold it; if *gong* means well crafted, how can it be held…as for the form of the character, it looks like the form of a carpenter's square, so it must be a square" (Yang Shuda). In ancient China, "*gong*" shares the same character origin as "巨(矩" for two kinds of instruments as rulers used by craftsmen, indicating "rule or principle" and eventually extended to mean rules or laws in the universe. In the silk drawings of Fuxi and Nüwa from the archeological discovery in Xinjiang Autonomous Region, Fuxi and Nüwa as the first ancestors of human species hold rulers respectively. They have human heads and snake bodies with snake tails copulating in the sphere of the sun, the moon, and the stars; their rulers representing the criterion for ruling heaven and earth (Zhang Xinghai 2004). As can be seen from this, "*gong*" has some inner links with the laws of nature, and our ancient ancestors have strong responses to the unified order among heaven, earth, and man. The title of the book *Tian Gong Kai Wu* reveals the intrinsic link between the works for the exploration and nature. "Tian Gong" originated from "Lai Tao Mo" in *Collection of Ancient Texts* (*Shang Shu*) where it is said: "Do not set up titular positions, the works of nature (*tian gong*) must be carried out by man." So here *tian gong* literally indicates the intentions of nature and then figuratively refers to the "craft" works of nature, in contrast with handicrafts of man. "Kai Wu" originated from "Xi Ci Shang" in *The Book of Changes*, where it is said: "*The Book of Changes* reveals the essence of things (kai wu) and therefore makes the enterprise possible. All it does is summarize the laws of nature." Song Yingxing, the author of *Tian Gong Kai Wu*, combined both concepts of "*tian gong*" and "*kai wu*" and expressed his emphasis on the harmonious combination of "the works of nature" and "the works of man." He, on the one hand, advocated acclimatizing to the works of nature and, on the other, had this thought of technological philosophy that to develop and produce useful "things," one needs to fully utilize "the works of man" aligned with one's subjective initiative. In the account of the craft of extracting silver in the volume of *The Five Metals*, Song Yingxing elaborated on "the two-step method of the extraction," admiring the wonder of the extracting craft as the result of the works of man by means of the works of nature – "the fine combination between the works of man and the works of nature can be revealed to some extent" (Yang Weizeng 1991, pp. 47–53). Here we see Song Yingxing celebrating both the works of nature and the works of man.

Harmony Between "Instrument (器 qi)" and "Rite (礼 l)i," "Technique (技 ji)" and "the Tao(道 dao)"

In remote antiquity, witchcraft and mythology played dominating roles in human civilization. Accordingly, the system of witchcraft rites and the techniques of "instruments by rites" appeared. The "instruments of rites" are not only the physical embodiment of techniques but also the physical embodiment of system, as well as the manifestation of the "laws of nature" and the "rules of man." *Book of Diverse Crafts*, as the account of the norms and manufacturing techniques for the official production of handicrafts in the Spring Autumn Period, reflects the system of the rite instruments as "establishing system by rites and observing rites by instruments" in ancient China, as well as the corresponding relationship between the norms of handicraft techniques and the social and ethical norms in ancient China. For example, the book gives an account of the material for jadesmithing strictly designated according to the rites of the feudal classes: "The emperor's rite jades must be made of pure jade, the minister's rite instruments made of four jades and one stone, the marquis's made of three jades and two stones, and the count's made of half jades of impure quality and half stones" (Wen Renjun 2008, p. 126, Xiao Ping 2005, pp. 23–25). In terms of the radian of the bow making, it declares: "The emperor's bow has the radian of nine bows, the duke's has that of seven bows, the senior official's has that of five bows, and the serviceman has that of three bows" (Wen Renjun 2008, pp. 133, 144). "This radian is measured by the number of bows that can make a full circle, and the different radians represented by the numbers of 'nine, seven, five, three' demonstrate the bow system and the match between the different social classes" (Xiao Ping 2005, pp. 23–25).

Not only do the instruments serve the rites but techniques also originate from the Tao and serve the Tao, and techniques can also lead to the Tao and therefore reach harmony between the techniques and the Tao. Song Yingxing believed, "Nature has the obvious Tao, which can be manifested by different means, except that man does not see it easily." However, man can perceive the "Tao" by technological practice and learn that "Tao" in practice. "The butcher carving the bullock" is a Chinese household story, describing the high skill of the butcher who reaches perfection in carving by constant practice and a thorough understanding of the essential structure of the bullock. "Essentials for Keeping Good Health" in *Zhuangzi* is a fine example from the technique to the Tao (Wang Qian 2005, pp. 84–89).

Harmony Among "Heaven," "Earth," "Material," and "Craft"

"Four elements must be well combined to produce fine work: the right time from heaven, the proper space from earth, the best quality from the material and the deft craft from man. Without the right time from heaven or proper space from earth, even the best material and craft will not enable fine works" (Wen Renjun 2008, p. 117). From the author's view in *Book of Diverse Crafts*, the technological development requires the four key elements: heaven, earth, material, and craft. In relation with

Aristotle's view of technological "four elements," material representing the physical cause and craft representing the purposeful cause, the book includes, for technological development, the additional prerequisites of "heaven" as the time dimension and "earth" as the space dimension. It points out that without the proper time and space, even the fine material and skillful craftsman will not enable fine works. "The knife from the State of Zheng, the chopper from the State of Song, the cutter from the State of the Lu and the sword from the State of Wu and Yue, will not be five works any more if their production places are changed." "Heaven generates things in one season and kills things in another." All these are due to the causes of the time of heaven and the space of earth. Consequently, in technological development, only by means of combining the four elements of heaven, earth, man, and material can the growth of the techniques be ensured.

In addition to the direct account of the relationship between technological development and the "time of heaven" and the "space of earth," the specific technological crafts and operational processes described in *Book of Diverse Crafts* and *Exploration of the Works of Nature* much involve the thoughts and principles of harmony between man and nature to ensure the implementation of technology. The two chapters of "Craftsmen Constructing the Capital City" and "Craftsmen Planning the Capital City" in *Book of Diverse Crafts* concern the description of city planning by "measuring the elevations of land by a level," "ensuring the erectness of pillars by the shades of light," and "determining the four directions by observing the stars." In Yang Huan's and Zhang Qianli's views, these two chapters involve the idea of the correspondence between heaven, earth, and man, where three gates are designed in each direction of the capital city walls, amounting to twelve gates, corresponding to the "twelve units counting time" (十二辰 *shi er chen*) in ancient China, and the five chambers in constructing the house represent the reverence of the five elements (五行 *wu xing*) in the Zhou Dynasty (Yang Huan and Zhang Qianli 2007, pp. 81–83).

Harmony Reflected in Chinese Medicine

In addition to the harmony in the practical techniques in agriculture and handicraft industry, harmony also penetrates the development of Chinese medicine which takes man as the object. The philosophical basis of Western medicine originates from the philosophical idea of "separation between the substance and I" while Chinese medicine is based on the "involvement of man and nature" and the "harmony between nature and man." Such Chinese methodological principle is holistic rather than reductionist. Chinese medicine emphasizes the principle of holistic harmony both in treatment and in health care.

The Orthodox Classic of Huangdi is an important theoretical classic of ancient Chinese medicine and pharmacy as well as an important representative work for the thought of holistic harmony. According to the book, man like everything on earth is the result of the regular changes of *yin* and *yang* in nature. Man involves nature and corresponds with nature. The chapter of "The Preservation of Health" in Part I of the book says: "Man is born on earth and is nourished by heaven; the combination of heaven and earth makes human life possible." Therefore, "between heaven and earth, within nature, everything either as big as a town or as small as human organs corresponds to the *qi* of nature" (Xie Hua 2000, p. 10). Man is the product and part of nature, and therefore, the structures of human organs and the function of metabolizability and movement follow the laws of nature, restricted by the laws of *yin* and *yang* and *wu xing*. The seasonal changes in nature also bring the changes in human function and energy. The relevance and correspondence between man and nature provide the theoretical basis for the prevention and treatment of diseases. The book starts with the general principle for preserving health by the statement of Qibo: "Imitate *yin* and *yang*, and balance the methods of preserving health." *Yin* and *yang* are not only the basis for all changes in the universe but also the causes of the changes of *qi* and blood (气血qi and *xue*). This is because both man and everything in the universe belong to nature. The *yin* and *yang* in the universe are external, while the human *yin* and *yang* are internal, both inducting and affecting each other. For the preservation of health, the internal yin and yang must imitate the external yin and yang, that is, our daily lives must follow the laws of nature to reach the harmony between man and nature.

In the article "The View of Harmony between Nature and Man in *The Orthodox Classic of Huangdi,*" Qu Limin points out the manifestations of the thought of harmony between nature and man in the book: (1) Man and nature are isomorphic, the structure of human body resembling the structure of heaven and earth. For example, "the heaven holds the sun and moon while a human being has two eyes. The earth has nine parts while a human being has nine apertures. The heaven has wind and storm while a human being has joy and anger. The heaven has thunder and lightning while a human being has voice. The heaven has four seasons while a human being has four limbs. The heaven has five tunes while a human being has five internal organs. The heaven has six melodies while a human being has six hollow organs" (Xie Hua 2000, p. 10). (2) Man and nature are congeneric. Classifications can be conducted in terms of the existence in heaven of the directions and positions, seasons, climate, constellation, and the number of creations; the existence on earth of different qualities, five types of grains, five types of animals, five tunes, five colors, five tastes, and fives smells; and the existence in human body of five internal organs, five pitches, five wills, pathological changes, diseased locations, and such classifications of five elements. (3) Man and nature are alike. From the known phenomena in nature, the hidden functions of internal human organs can be discovered. For example, from the knowledge of the movement of heaven and the tranquility of earth, it can be inferred that the stomach, large intestine, small intestine, and bladder share the characteristics of movement with the function of purgation not storage, and the heart, liver, spleen, lungs, and kidney share the characteristics of tranquility with the function of storage not purgation. (4) Man and nature share the same rhythm. The book reflects the concept of the combination of the time and space in their proper order. It emphasizes the circadian rhythm of the human body as the physiological and pathological rhythm closely related to astronomy and meteorology.

As a result, there appear different rhythms such as good and bad fortunes, day and nights, and the moon and the sun (Qu Limin 2007).

From the view of the "harmony between nature and man," the ancient Chinese medicine insists on the holistic methodology both in disease treatment and health preservation. Contrary to the insistence on the reductionist methodology of Western medicine, the holistic methodology takes man and nature as a whole unity, with the belief that the human body is affected physiologically, psychologically, and pathologically by the changes of seasons, climate, day and night, and the movements of the sun and moon. In addition, the movements of the human organs, blood circulation, spirits, and moods keep in harmony with one another and make up a whole unity, together forming the orderly activity and process of life. Thus, the key to preserve health is first of all to adjust to the changes of time, that is, to follow the changes of the four seasons, adapt to and regulate the order of life, and to strengthen the adaptive capability to the environment. This is what is called "to acclimate is to keep fit, to do otherwise is to encounter adversaries, adversaries lead to changes, and changes lead to diseases" (Cheng Yajun 2009, p. 716). The second is to balance one's moods, keep indifferent to fame or benefit, avoid losing one's natural disposition by nonego, or disturb one's inner tranquility by lusts and desires. The Chinese medicine believes that the basis to preserve health is to preserve the spirit first. The spiritual activities are induced by the five internal organs, and then they retroact to the organs, affecting the physiological activities. Thus, the chapter of "The Basic Organs" in Part II of the book says: "The human will can dominate the spirit, control the soul, adjust to the changes of climate and balance the mood." "When the will is focused, the spirit concentrates, the soul calms down, regret and anger retreat, and the five internal organs will not be affected by the evil forces" (Yu Rui and Cheng Zedong 2004). "The calm spirit and will and all in harmony are the basis to preserve health" (Li Dingsheng and Xu Huijun 2004, p.161). The basis to "preserve the spirit" is to avoid lusts and desires, keep both heart and spirit calm, and cultivate one's disposition and strengthen one's body, so as to realize the harmony between body and soul and maintain the balance and harmony between *yin* and *yang*.

A Brief Case Study in a Water Conservancy Project in Modern China

Although many fine examples were set in the technological development in ancient China, following the Chinese traditional view and principle of harmony between man and nature, some negative cases occurred in water conservancy in modern China under abnormal historical and ideological circumstances. One typical example is the construction of Sanmenxia water conservancy project. The city of Sanmenxia is located on the western border of Henan province. It lies at the junction between Henan, Shanxi, and Shaanxi provinces, bounded with Luoyang in the east, Nanyang in the south, Shaanxi in the west, and overlooking Shanxi across the Yellow River in the north. The city proper is situated on the slope of the southern bank of the Yellow River. Blocked by Taihang Mountain between Tongguan and Mengjin in Shan County, Henan province, the Yellow River, with its enormous hydraulic power, forces three channels along the mountain passes. These three turbulent streams are called the three gates, the "gate of men," "gate of gods," and "gate of ghosts" from the east to the west.

From the Western Han Dynasty to the Republic of China, the Yellow River has been the main water route for transportation. It has almost become a symbol of the Chinese race in defiance against its destiny to pilot the boats in the turbulent yellow water. Sanmenxia has a unique feature on the Yellow River in that it controls 92% of its flood and silt and as a consequence is the cause of repeated concerns. In April 1954, the National Planning Committee sets up the Yellow River Project Committee. Under the supervision of Soviet experts, the committee started to plan the Yellow River project. In the planning report, the Sanmenxia water conservancy pivotal project was chosen as the first key project in the comprehensive utility of the Yellow River. Its water storage level was to be 350 m and its total volume 36,000,000,000 cubic meters. Its main task was designed as follows: (1) To reduce the flood flow from 37,000 cubic meters per second to 8,000 cubic meters per second on the upper part of the river for every 1,000 years. Thus, the disaster of flood could be completely avoided, and the flood threat on the lower part all but eliminated. (2) To retain all the silt in the upper part, release clear water, and accomplish the goal of "Clear Yellow River" so that the lower river bed would not rise due to silting. (3) To regulate the water volume of the Yellow River to irrigate 22,200,000 *mu* of land in the first stage and 75,000,000 *mu* in the future. (4) To provide hydropower of 900,000 kW, producing 4,600,000,000 kW-h. (5) To improve conditions for shipping on the lower part of the river. The conclusion of the report for the project sounded very desirable: it is fair to state that enormous and comprehensive benefits were envisaged.

In 1956, the *preliminary design points for the Sanmenxia project* was completed by the Soviet "elder brothers," and the gigantic project was irreversibly launched. On November 25th, 1958, the closure of the river was completed. In June 1960, the dam was constructed up to 340 m high, already capable of flood retention. And yet the consequence has proved to be disastrous.

The construction of the Sanmenxia Reservoir caused 90% of the sand and mud from the upper river from being discharged, causing silting and raised the water level, bringing about yearly flood disasters. Instead of clearing the water, it led to various problems such as the wash and erosion of the river bed, deterioration of the ecological environment, increase of saline-alkali soil, loss of farmland, forced civilian migration, and damage to precious cultural relics in this area of ancient civilization. The causes of these mistakes can be summed up as follows: (a) The project is based on the design of the former Soviet Union Leningrad Hydropower Institute. However, the institute lacked the experience of constructing water conservancy projects on rivers with so much sand as the Yellow River, and it had no knowledge of the water conditions in the Yellow River. (b) No overall evaluation was carried out of the benefits and damage the reservoir would yield. (c) And very significantly the enormous impact on humans was ignored.

Such bitter lessons must be drawn: the consequences could have been avoided if the ancient Chinese traditional view of harmony between man and nature had been followed. Modern technological development has definitely grown more varied and complex and has by far surpassed the ancient technological methods; however, the basic principles and concepts in the relationship between man and nature ought to be seriously considered and carefully observed according to the actual circumstances of each area and project.

Conclusion: The Characteristics and Practical Implications of the Harmony-Oriented View of the Technological Development

From the above reviews of the technologies in agriculture, handicraft industry, and medicine, it becomes clear that the thoughts of the harmonization with nature and the unity between nature and man serve as the main clues that permeate the whole technological activities in ancient China. Harmony in all its rich sense became the guiding principles for ancient Chinese technological development. Harmony is both the purpose for the development and the methodology for the direction of the development. Particularly this methodology is mainly characterized to include the holistic principles of emphasizing the integrated affiliation, the relationships among the different elements, as well as the technological strategies of differentiating diverse elements, considering specific situations, and keeping pace with time. The above case study illustrates a negative example from the modern practices in China and hence the importance of understanding and implementing such Chinese ecological views and methods in the process of modern technological development. All these have strong practical implications to today's reconstruction of the harmonious relationship between man and nature and the construction of sustainable strategies of technological development.

The Holistic Principles of Emphasizing the Relationship Between the Parts and the Whole

In the view of the harmonious technological development, the ecological system including man and nature is the whole unity of reciprocity and reliance. Man is only one element of the whole system. Man is neither the center of the system nor can he break away from the ecological network. Just as Zhuangzi said, "I was born with heaven and earth and everything in nature becomes the oneness with me" (Chen Guying 1983, p. 88). We, like everything else in the natural environment, are only part of the whole system. In the Western modern view of development, man is considered as the dominator of the world and the natural environment as the object to be conquered. Following this point of view, human beings have been seeking modernization, ignoring the effect humans have had on other species and the environment, causing severe damage to the ecological system of the earth. Such behavior has not only threatened the existence of other species but has also caused great danger to the existence of human beings themselves. “The bound Prometheus finally shook off the chains, science provided him with the unprecedented power, and economy endowed him with the ceaseless driving force.” However, “the gospel that modern technology brought to us has already turned to the adversity, and even the disaster” (Jonas 1984). And the conquest of nature is already extended to the conquest of human beings themselves. Under such circumstances, to review the ancient Chinese harmony-oriented holistic view of nature, and to reinvestigate the thinking pattern of the industrial civilization, has great significance in constructing the sustainable relationship between man and nature.

The Emphasis on the Practical Wisdom of Keeping Pace with the Time and Adjusting Measures to Local Conditions

It can be clearly seen from the above that in the Chinese view of harmony, the process and dynamism are emphasized, that is, the strategy of human action must change according to the changes of nature. This is of special importance for today’s challenge to tackle the uncertainties of high technology and for determining the proper ethical basis for technological development.

The Timely Strategy: Correctly Appraise the Situation

The timely strategy requires that we correctly appraise the situation, that is, to make timely judgments and carry out a thorough evaluation of any technological development under the current existing regime including nature at that time. The key to the timeliness and correct appraisal is “time.” “Time” is an important concept in Chinese philosophy. In terms of the relationship between man and nature in particular, the practical wisdom of correctly appraising the situation in Chinese philosophy plays a dominant role. We are now faced with a world of rapid technological development. Technology is not just keeping pace with science but in many aspects is far surpassing science. The indication is that technology may have already entered the market and our life without us knowing the mechanism and basic theory of the technology not to mention how it impacts on mankind and the environment. Thus, it is imperative in respect to technological development that research is carried out in all aspects of its adoption, to observe ethical consequences, make timely relevant laws, enact regulations and formulate ethical codes, and pilot the healthy development of science so that there is a sustainable development of technology and also a sustainable development of human beings and the whole human race.

The Dynamic Strategy: Keep Pace with the Time

The dynamic strategy requires that we take an open and dynamic attitude, make timely adjustment taking account of the relevant ethical and legal norms according to the specific technological development and the social acceptability of the technology, "act judiciously," follow and seize the opportunity, and keep pace with the "time." The balance to be adopted is that of respecting tradition and facing the challenges of the future.

The main feature of the dynamic strategy is to ensure the controllability and revisability of our behavior. The prerequisite is to acknowledge the gradual process of our understanding of science and technology and also to recognize our unknowingness and ignorance. We must not act blindly before conditions mature. Meanwhile, we must acknowledge the understanding of science as a process of development and the explicability of science. New technology is always accompanied by risks. To understand such risks requires a certain process. We must make the use of existing and safe technology a priority, take courses of action that are, whenever possible, reversible supported by correctable strategic measures. When new technology matures and people are ready to accept it, not least of all psychologically, we must adjust our strategy of action. To insist on a dynamic and harmonious strategy of development with the view of keeping pace with the time, we must make timely adjustment of our understanding of specific technological risks and find measures of evaluation that establish and develop an open technological view of the dynamic of systems, so that we can select, develop, and utilize the technology in time.

The Local Strategy: Adapt to Local Conditions

The local strategy requires that we differentiate as between diverse elements, pay attention to different contexts of technological development, and adopt different technological strategies of development according to different regions. Although in terms of today's modern technology, the employment of technology no longer relies on the geographical conditions, yet the cultural features, the value tendencies, and the differences in local economies and state of cultural development still need to be considered. The acceptability of the same technology may differ greatly at different regions with different cultural heritages. Thus, in the technological decisions, we must pay full attention to regional characteristics and carefully consider the compatibility of the technology to the local culture (including their value concepts) and the economic tolerance or the adoption of a new technology. We must make the technological strategy of development the one that best suits the local conditions so as to maintain the harmony between man and technology, man and man, and man and nature.

Mr Qian Mu once said, "The concept of the harmony between nature and man is the greatest contribution to mankind from Chinese culture" (Qian Mu 2009). Mr Ji Xianlin, after quoting Mr Qian's remark, said, "What I'd like to clearly add is that the "harmony between nature and man" means the oneness and peace between man and nature without talking about the conquest or the conquered" (Ji Xianlin 2009). We believe that to harmonize with nature is not only the core value of the ancient Chinese technological view of development, but it should also be the direction and guiding principle for our future technological development.

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Chapter 23
Lynn White Revisited: Religious and Cultural Backgrounds for Technological Development

Martin Meganck

Abstract Since the beginning of the awareness of the environmental crisis, studies have tried to trace back the historical and ideological roots of industrial evolution. Many of these studies indicated elements of the Judeo-Christian tradition as at least co-responsible. Some 40 years later, this chapter overviews some strands of the discussions these studies have provoked, especially concerning the alleged anthropocentrism of Judaism and Christianity and their disenchanting attitude toward nature. These traditional ideas are confronted with insights from Marcel Gauchet's philosophy of religion, with inputs from other religions, and with empirical data from recent surveys.

Keywords Disenchantment of nature • Anthropocentrism • Judaism • Christianity • Hellenism

Introduction

When did it all begin? While environmentalists often refer to Rachel Carson's *Silent Spring* (1962) as "the real beginning" of the environmental movement, philosophers studying environmental and technology issues mostly choose the 1967 article "*The Historical Roots of our Ecologic Crisis*" (written by the American historian Lynn White) as a point of reference, at least in the historical sense, and often also as to the ideas developed in it. Both for Carson and for White, important precursors can be indicated, so that coining their texts as "starting points" is somewhat artificial.

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Yet both writers had novelties in their statements which helped legitimize their reputation, and the mere fact of the frequent referrals to their texts is significant in itself. Carson's book evoked the possibility of human activities pushing environment to the limits of its carrying capacity for sustainable life – an idea later taken up in *Limits to Growth* (Meadows 1972) and more recently in mathematical models used to predict combined environmental, climatologic, demographic, and economic evolutions. Lynn White took up arguments from the realm of discussions about religion, culture, and technology but placed them in the context of the raising awareness of the environmental crisis, where they sounded as an accusation against the Judeo-Christian roots of Western culture. With religion coming into play, White seems to have touched a very sensitive nerve, and his article gave rise to a multitude of comments, interpretations, and criticisms (White 1973; Mitchell et al. 2006).

The Ideas Behind "The Historical Roots of Our Ecologic Crisis"

White's article emphasizes first of all that "modern technology and modern science are distinctively Occidental" (White 1967, p. 1204). This is not meant to deny achievements in, for example, China or the Arabic world; on the contrary, many technological innovations had their historical roots in Eastern cultures and were – in successive movements – imported from the East. Yet, throughout the Middle Ages already, the Occident saw scientific and technological development exceeding that in the Orient. In order to understand this development, White wanted to examine some of the "fundamental medieval assumptions and developments," adding "Human ecology is deeply conditioned by beliefs about our nature and destiny – that is, by religion" (ibid., p.1205). And for Western Europe, religion mainly means Christianity, which cannot be properly understood without also referring to its Judaic roots. And Christianity (especially in its Western form) is, according to White, "the most anthropocentric religion the world has seen" (ibid.).

For illustrating Christianity's anthropocentrism, White refers to the story of creation that Christianity inherited from Judaism. In Gen 1:26–28, mankind is created as an "image of God" and receives the mission to "fill the earth and subdue it" and to rule over the animals. In Christianity moreover, the special nature of mankind is reemphasized by God's incarnation in Christ: what more can one want as a proof of the God-likeness of man? Furthermore, Western versions of Christianity developed the tradition of "natural theology": the study of the created nature itself was a legitimate way of understanding the Creator. For many historically important scientists, their scientific work was intricately linked to faith and theology. White mentions here Roger Bacon, Galileo Galilei, and Sir Isaac Newton (ibid., p. 1206).

The history of Christianity is not univocal in this respect, though. Christian churches of Byzantine or Orthodox tradition tend to be more contemplative and hence less inquisitive or active. And even in the history of the Western Catholic church, there are figures like Saint Francis who "tried to substitute the idea of equality of all creatures, including man, for the idea of man's limitless rule of creation" (ibid., p.1207). Although Saint Francis is in this sense atypical for the Western Christian tradition, White proposes him as a "patron saint for ecologists" (last sentence of White's article).

The thesis of Judeo-Christian anthropocentrism as a dominant cause for mankind's impact on the environment is the most discussed aspect of White's text. Minteer and Manning (2005) distinguish some other themes that could lead to further discussion. Human interference with the environment is almost self-evidently described as an "inherently negative disruption of some sort of preexisting and static ecological order" (Minteer and Manning 2005, p. 167). But the idea that the "natural state" of the environment is equilibrium can severely be questioned. Or, the suggestion that in an older model of agriculture, man was in close contact with nature, whereas modern agriculture brings disruption and alienation. White also seems pessimistic about democracy's possibility to deal with the environmental crisis. And finally, White does not consider the possibility of milder forms of anthropocentrism, where nature would be less subject to exploitation.

Old Wine in New Wineskins?

White was not the discoverer of the theme of anthropocentrism in Christianity and of the desacralization of nature in monotheistic religions like Judaism and Christianity. For centuries, philosophers and theologians had been mentioning these characteristics while examining the link between Christianity and scientific or technological development. Van der Pot (1985, pp. 38–39) considers the English scientist Robert Boyle as the first author to point out that "[T]he veneration, wherewith men are imbued for what they call nature, has been a discouraging impediment to the empire of man over the inferior creatures of God". And in the 4th Century AD already, Saint Gregory of Nyssa wrote that "to conclude the Creation, man was introduced: not contemptuously subject to the latter, but from his very beginning dignified to be king over what is subordinate to him" (Van der Pot 1985, p. 48).

In the beginning of the twentieth century, several authors developed this theme further. Among them is the German sociologist Max Weber in his elaborate study of the historical and ideological roots of science, technology, and capitalism (Van der Pot 1985, p. 39). He indicated that where the relationship between humans and nature is dominated by magic, rationalization of human actions (like in economy and technology) is severely inhibited. Judaism, on the contrary, is characterized by a hostility against magic, and Christianity (especially in its ascetic protestant tendencies) inherited this attitude. Other thinkers coming to similar conclusions include Max Scheler and Arnold Gehlen.

Considering these precursors, it may seem surprising that White's article elicited so much discussion. In fact, the basic ideas behind it were not new in themselves.

But until then, they had mainly been linked to the occurrence of scientific and technological progress and in this respect endowed with a predominantly positive connotation. White, however, uses language with negative connotations: he puts the discussion in a context of *crisis*. Human interactions with nature are not just use or even domination but end in *exploitation*, and to the extent that the ecologic effects are out of control, he considers Christianity to *bear a large burden of guilt*. It seems that this accusatory tone contributed to a large extent to the eagerness with which many commentators started discussing, confirming, or refuting White's theses (Hawkin 1999).

Add to that the fact that the environmental problem in itself was a relatively new theme on the public agenda. Rachel Carson had set the tone in indicating certain forms of pollution as threatening for the future of mankind – and nature. The oil spill of the Torrey Canyon in 1967 (as one of the very first major environmental accidents) was very effective in visualizing the possible threats of large-scale industrial operations. Other themes like the limited availability of raw materials, or the possible impacts on climate, got at the time little or no attention, or had yet to be discovered (Zweers 1991).

Dominion Terrae: Disenchantment of Nature Combined with Anthropocentrism

According to Wildiers (1989) and Boersema (1991, p. 31), all human thinking about a deeper meaning of life has a "metaphysical triangle" as its backcloth: it has to find a proper positioning for man, nature, and the Divine (see Fig. 23.1). The triangle allows visualization of the mutual relationships between the corners of the triangle. The distance and the elevation of the corner "God" can be an indication for the degree of transcendence of God above nature and/or man. In a pantheistic view, the corners for "God" and "nature" (and man?) would coincide and merge. In worldviews in which man is considered as a creature like nature, "man" and "nature" will be on a same horizontal line, and this line being shorter the more man is merely seen as part of nature. Triangles in which the position of "man" is elevated above "nature" would then be symptomatic for a worldview in which man is not merely a creature like the rest of nature but is endowed with some degree of divine dignity.

It can be useful now to take this "metaphysical triangle" as a framework for visualizing and discussing the ideas raised in White's article. The "dominion terrae" idea, which places humans in a dominant position compared to nature, can be seen as a combination of anthropocentrism (resulting from the privileged relationship between God and man) and disenchantment of nature. For each of these sides of the metaphysical triangle, verses from the very first chapters of Genesis can be used as illustrations (and foundations?) of these attitudes. But scholarly methods in exegesis lead to results that seem less conclusive.

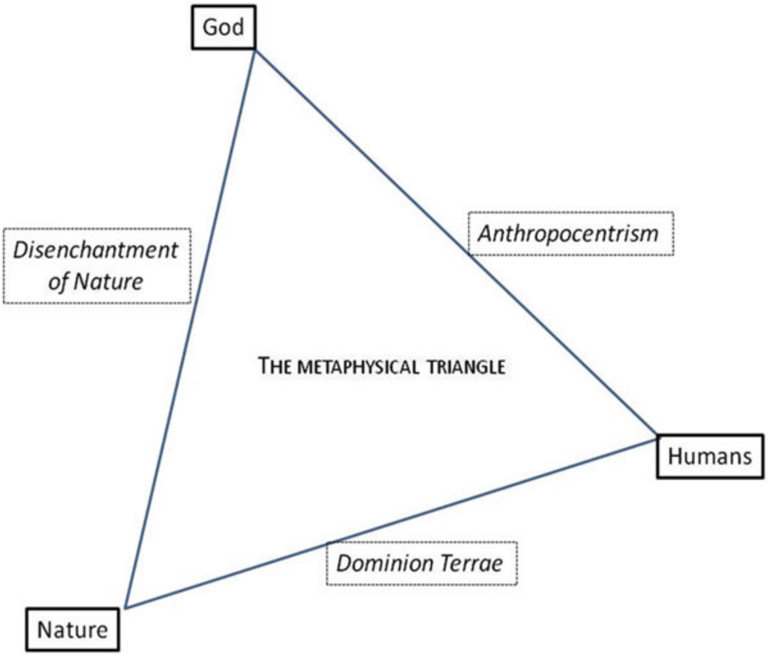

Fig. 23.1 The metaphysical triangle

Biblical Backgrounds: A First Reading

White himself links Christianity's attitude toward environment directly to the stories of creation which Christianity inherited from Judaism. He did not enter into the details of the text, however. Exegetic studies seem to support White's view at first but give a more nuanced image in the end. In Genesis 1:26–28, man's mission in the world is expressed with words like "subdue" and "have dominion":

> Then God said, "Let us make man in our image, after our likeness; and let them have dominion over the fish of the sea, and over the birds of the air, and over the cattle, and over all the earth, and over every creeping thing that creeps upon the earth." So God created man in his own image, in the image of God he created him; male and female he created them. And God blessed them, and God said to them, "Be fruitful and multiply, and fill the earth and subdue it; and have dominion over the fish of the sea and over the birds of the air and over every living thing that moves upon the earth."
>
> (Gen 1:26–28, Revised Standard Version (RSV))

Genesis 2:18–20 is also often interpreted as establishing man's domination over nature (or at least, over the animals), especially in view of the power that is given to words and the significance of name giving in Semitic cultures. "So out of the ground the Lord God formed every beast of the field and every bird of the air, and brought them to the man to see what he would call them; and whatever the man called every living creature, that was its name"(RSV). In Genesis 2:15, however, man's mandate over nature takes a different tone: "The Lord God took the man and put him in the garden of Eden to till it and keep it" (RSV). Other versions translate the second half of this verse as *to dress it and to keep it* (King James Version), *to cultivate it and keep it* (New American Standard Bible), or *to work it and take care of it* (New International Version).

One way to examine the correctness of the anthropocentric interpretations of these texts is to refer to the original Hebrew text. In Gen 1:26–28, the Hebrew words indicating man's relationship to the animals and the earth are *radah* and *kabash*. *Radah* has significations in the field of treading or squeezing, like one does with grapes in order to make wine. In the context of hostility among humans, *radah* has a meaning of domination, and it is also used to express the sovereign power of kings. *Kabash* has connotations in the field of warfare (subjection of the defeated) or slavery (to enslave). With the evocation of these significances, man is indeed placed in a position of dominion and power over nature (Wénin 2007, p. 41, Hoge 1991).

Gen 2:15 however uses the words *'avad* and *shamar*. Significances of *'avad* are to be found in the field of work: to cultivate the ground, to build, to serve, and even to worship or to honor (when used in a religious context). *Shamar* has meanings in the field of watching over something, guarding or preserving. These words do thus not have the same connotation of violence or power as compared with the words used in Gen 1:26–28 (Mitchell et al. 2006).

Biblical Backgrounds: Widening the Interpretive Background

Whereas the first circle of meanings of the terms appearing in the Biblical stories of creation has a rather obvious tendency, some theologians extend the field of associations, thus opening a much wider range of possible interpretations. For example, Kanayankal (2009, pp. 67–95) gathers a set of comments associating the meanings of *radah* and *kabash* with royal authority (eventually conferred upon mankind by God). But the tradition of "kingship" in the ancient Near East is loaded with ideals of wisdom, justice, righteousness, and taking care of the well-being: in "conjugation with a vision of just governance in which oppression is actually crushed" (Kanayankal, p. 80). An interpretation in this sense would bring the scope of even such dominant words like *radah* and *kabash* closer to the language used in Gen 2:15.

Kanayankal continues his work by elaborating the theme of *Sabbath* in biblical tradition. With Sabbath, the human attitude of dominion and activism is mitigated by moments of withdrawal, rest, and reorienting toward God. Gulick (1991, pp. 187–188) points out that the *covenantal relationship* between God and humans is often seen as essential in the Bible. The "rainbow covenant" between God and Noah (Gen 9:9–10) includes the animals within its purview and was often used as a symbol when the World Council of Churches adopted *"Justice, Peace, and the Integrity of Creation"* as a working theme in the early 1990s (De Tavernier and Vervenne 1990). Yet Gulick concludes that the Sinaitic covenant is essentially between God and humans and that nature appears above all as *a resource, a potential punishment, or a gift*. Also the Ten Commandments (Deut 5), or the shortened ethics outline in the Gospel ("You shall love the Lord your God […] and your neighbor as yourself" (Lc 10:27)), do not explicitly mention nature as an object of human care or responsibility.

Others interpret the abovementioned verses in Gen 1–2 in terms of a *stewardship*. God does not give creation to man in property, with the full discretionary powers this would entail. God remains the real owner of creation, and man has to account for the way nature is treated. The idea of a *co-creatorship* has also been put forward: when God created man in his image and gave him a divine mandate, God's creatorship is with that mandate co-transferred upon mankind. Creation was thus not complete on the 6th day, and human history can be seen as the continuation or completion of creation. Similarly, though slightly different, human work (although originally presented as a punishment) has been interpreted as a way of *restoring the original paradise* from which man had been expelled after the original sin, well aware of the "eschatological reserve": the fundamentally utopian character of the Kingdom of God.

Preliminary Conclusion

It is quite easy to find Biblical references strengthening White's view when he points to the Judeo-Christian tradition as a historical background for Western anthropocentrism. Genesis 1 can be read as a story in which the Jewish tribes, with their nomadic background, position their God as a creator above the other, nature-bound gods of the sedentarized surrounding peoples (the beginning of monotheism). The Old Testament is also very critical in distinguishing God's real prophets from alleged prophets who engage in magic practices and evoke the spirits of nature. And throughout the texts, the relationship between God and his people appears as special and privileged compared to the position of nature. There are places where the beauty and wonders of nature are described and praised (like in Job 38–42); and yet even in these instances nature primarily serves as a signal of God's might and transcendence. So in Psalm 8, the praise of nature's beauty finally results in an accentuation of man's privileged position:

> When I consider Your heavens, the work of Your fingers,
> The moon and the stars, which You have ordained;
> What is man that You take thought of him,
> And the son of man that You care for him?
> Yet You have made him a little lower than God,
> And You crown him with glory and majesty!
> You make him to rule over the works of Your hands;
> You have put all things under his feet,
>
> (Ps 8:3–6, New American Standard Bible)

Mitigations of this anthropocentric view rely on theological connotations linked to the interpretive contexts in which the Bible can be put, such as the harmony-oriented images of the covenant or of a "Kingdom of God."

Anthropocentrism and Disenchantment of Nature in Christianity

Relying on the foundational texts for a tradition is but one way of understanding that tradition. It has to be completed by an analysis of the *Wirkungsgeschichte*. At some stages in the development of a tradition, the foundational texts are referred to explicitly. This may especially occur on moments of crisis, either to go "back to the roots" (with sometimes a fundamentalist reading of the texts) or in a movement of *aggiornamento*, trying to reinterpret the texts in the new circumstances. Reconstructing and reinterpreting the development of a tradition inevitably occurs in a combination of selective and constructive movements, and it is a challenge to do this in full respect for intellectual honesty.

Browsing Through History

Browsing through the history of Christianity and Western intellectual life, examples of an anthropocentric and disenchanting attitude are legion. A few examples:

- Fathers of the Church, commenting on God's incarnation in Christ, see herein also a divinization of man. So, for example, Saint Augustine (354–430): "Factus est Deus homo, ut homo fieret Deus." (*Sermo 13 de tempore*, PL39, 1097): "God became man, so that man could become God."
- On biblical grounds, Saint Thomas Aquinas (1225–1274) accepted that humans would kill animals. And where he yet wanted humans to refrain from cruelty against animals, he gives as a reason that this is "to turn the mind of man away from cruelty which might be used on other men, lest a person through practicing cruelty on brutes might go on to do the same to men" (*Summa Contra Gentiles* III, 112, trad. V. Bourke).
- There seem to have been a multitude of factors that lead to the condemnation for heresy of Giordano Bruno (1548–1600) (Rowland 2008). Some of them had to do with philosophical or theological orthodoxy, and his general rebellious attitude certainly did not help to placate the controversies. One of the difficulties was his pantheism: the idea of an inseparable unity between the infinite God and the infinite universe was found incompatible with catholic dogmas concerning, for example, sacraments and transubstantiation, which can only hold if the material world is seen as fundamentally disenchanted. Similarly, Pietro Redondi (1985) considers Galileo's trial to be inspired more by catholic sacramentology being threatened by his atomistic physics, rather than by the more commonly known cosmological disputes.
- In Descartes' dualism between *res cogitans* and *res extensa*, animals are on the merely material side; his view on animals is often resumed in the image of the *bête-machine*; man on the contrary is described as "*maîtres et possesseurs de la nature*" (masters and owners of nature) (*Discours de la méthode (1637)*).

- Francis Bacon (1561–1626) saw nature as something which was to be conquered, be it by obeying (in this case: studying) it: "Natura non nisi parendo vincitur" (*Novum Organon*).

Occasions where nature is valued more positively seem scarce by comparison. White already drew the attention to the figure of Saint Francis of Assisi (1182–1226): in a culture where fundamentally dualistic heresies like bogomiles and cathars saw material nature as emanations of evil, Francis' attitude wanted God's creation to be honored, including in its material expression.

It was not until the 1960s that environmental care emerged as a theme of public concern and discussion in society at large. The churches made no exception to this. One of the first mentions of ecology as a theological theme in Catholicism seems to have been the speech of Paul VI to the FAO, in which he urges mankind to "dominate its domination" (Nieme Kadiamonoko 2011, p.182). Other loci are the abovementioned campaign "Justice, Peace, and the Integrity of Creation" of the World Council of Churches in the 1990s and in the Catholic Church John Paul II's Encyclical *Centesimus Annus* (1990, n 37), which states

> At the root of the senseless destruction of the natural environment lies an anthropological error, which unfortunately is widespread in our day. Man, who discovers his capacity to transform and in a certain sense create the world through his own work, forgets that this is always based on God's prior and original gift of the things that are. Man thinks that he can make arbitrary use of the earth, subjecting it without restraint to his will, as though it did not have its own requisites and a prior God-given purpose, which man can indeed develop but must not betray. Instead of carrying out his role as a co-operator with God in the work of creation, man sets himself up in place of God and thus ends up provoking a rebellion on the part of nature, which is more tyrannized than governed by him.

In the *Catechism of the Catholic Church* (1992, articles 2415–2418), care for animals and nature is mentioned as a comment on the 7th (in other churches: 8th) commandment, "you shall not steal," where inappropriate use of natural resources is interpreted as a sin against the universal destination of the goods of the earth, including the interests of future generations.

Philosophical Backgrounds: The Greek Connection

In White's article, Christianity was mainly linked to Judaism as its historical background. However, it is often indicated that the Hellenistic culture which prevailed in the Mediterranean area in the first centuries of Christianity had a large influence in molding the young spreading religion. Influences of Greek philosophical currents can be found in the New Testament and in the writings of many of the Fathers of the Church. The political structure of the Roman Empire was also in the background when the hierarchical structure of the Church was canvassed.

Boersema (1991) is one author who has drawn attention toward the influences of Greek philosophy on two important moments of Christianity. A *first Hellenization* took place during the initial spreading of Christianity, due to a combination of anti-Judaic feelings in some tendencies of young Christianity itself and the overwhelming presence of the Hellenic culture in the Mediterranean area. A *second Hellenization* is to be found in the late Middle Ages and during the Renaissance, with the rediscovery of the old classic texts (often via their Arabic translations). Be it in different forms and proportions, Platonic, Aristotelic, and Stoic traditions all recognize a hierarchical order in the cosmos, with man being at the top of that order (Aristotle) or being the main purpose of it (Stoa). Hierarchical thinking (also present in the *dominion terrae* idea) can be traced back both to Aristotelic and Platonic traditions. To the extent that it is in the "nature" of plants and animals to be at the service of mankind (Aristotle) and that "nature" is a "telos" with a normative meaning in his ethics, human use of plants and animals is accepted. Traditions rooted in Plato often accept a separation of a natural and some supernatural level. The dualistic body/soul anthropology in Christianity seems practically absent in Old Testament Judaism; one of the protagonists of this anthropology was Saint Augustine, under neoplatonic influences. Even the idea of monotheism, which is usually linked to the triad of Judaism-Christianity-Islam, had its adherents in pre-Christian Hellenistic thought: Ferguson (2010, p. 184) reports how Eudorus of Alexandria (1st century BC) developed his own interpretation of Pythagorean and Platonic ideas, resulting in the idea of an all-transcending One.

Disenchantment as an Inherent Trait of Christianity

The contemporary French philosopher Marcel Gauchet incorporated a philosophy of religion into his political philosophy. In his book *Le désenchantement du monde* (1985), he describes a specific kind of dynamics which seems present in "higher religions" in general and in Christianity in particular. This dynamics finally leads to *la sortie de la religion*. "*Sortie*" is used in a rather ambiguous sense: it indicates the disappearance of religion (religion leaving the floor) but also the result of religion (what comes out of religion).[1]

Religion, according to Gauchet, primarily deals with the principle of heteronomy, otherness, and dispossession of oneself in favor of the "beyond." In primal religions, transcendence is not experienced "spatially" but temporally. The gods surround humans in their living world but link them to the primordial past (Cloots 2008, pp. 9–11). Around 5000 BC, the state arose as a level of authority between the gods and the humans: the beginning of a movement in which power and politics inserted a growing distance between the gods and man. The temporal distance from primal religions turns into an ontological and spatial distance. Finally, in what Gauchet calls "higher religions," the gods are expelled from earth and are seen as completely

[1] In the English version of Gauchet's book, *The Disenchantment of the World*, "sortie" is translated as "departure"; this translation however does not fully render the ambiguity of the original French "sortie" (Cloots 2008, p.7).

different in an ontological sense. In Judaism, this "ontological duality is deepened into a real separation, through monotheism and creationism" (Cloots 2008, p. 12). Further, withdrawal of God from the world progressively enhances man's autonomy and independence. The paradoxical conclusion of this is that the greater the gods are, the more man is free (Gauchet 1985, p.64).

In Christianity, there is a specific logic through which this greater autonomy develops further (Cloots 2008, pp. 14–20):

- Christianity is a religion of *revelation*: God reveals himself, through history, but also through creation itself: God can be known through the "book of nature." The emphasis on transcendence is mitigated by *incarnation*: if God became man in Christ, this gives a proper dignity to the world. The religion itself indicates the world as a place of relevance, of concern. And as salvation passes through incarnation, the mission of changing the world is bequeathed to man. The notion of incarnation makes that Christianity never settles in neither mere submission nor escapism (although some movements in Christianity occasionally flirted with these attitudes). The world is a serious thing, requiring active attention.
- Finally, Christianity is a religion of *interpretation*. We do not know the *ipsissima verba* of Christ; we do have four gospels, which are interpretations already. And throughout the history of Christianity, that interpretation continues, either by *magisterium*, by tradition, or by *sensus fidelium*. The possibility of heresies, schisms, reformations, and dissidence seems congenital to Christianity. Hence, intellectual work is always part of dealing with revelation, thus stimulating autonomous thinking, philosophy, and eventually science.

At this point, it is no wonder that Christianity eventually leads to its own "sortie": it will have to submit to the ideas of reasonableness and humaneness. It accepts a full separation of the realm of the gods and the realm of worldly (political) authority ("Give to Cesar what belongs to Cesar, and to God what belongs to God" (Lc 20:25)). Whereas modernity is usually seen as a threat for religions, Gauchet describes modernity also as a result of religion.

Lynn White, as a historian, based his thesis mainly on his reading of history and on his recognizing a thread from early Judaism to the times of industrialization. Theologians, exegetes, and Church historians reworked his ideas, often finding elements confirming White's intuition as well as elements mitigating, contextualizing, or criticizing it. Gauchet's political philosophy of religion gives another, more philosophically constructed carrying canvas for White's intuition.

More than Anthropocentrism and More than Christianity

Two more threads are to be examined concerning the validity of White's thesis:

- Are there any other aspects of Western civilization which can be relevant for this discussion (besides the anthropocentrism/disenchantment debate)?

- What about other cultures? Can the observed similarities and differences between Judeo-Christian versus other cultures account for the differences in attitudes toward nature and in development of industry?

Time, Progress, and Work

From White's paper, the ideas of anthropocentrism and disenchantment of nature were distilled as the key elements in his search for the historical roots for the ecologic crisis. Almost casually, without really developing it, he also mentions the understanding of "*time*" in Judeo-Christian tradition as "*nonrepetitive and linear.*" In cultures with a static or cyclical view of time, the idea of "progress" is hard to conceptualize. In the most dominant currents of Greek philosophy, the idea of a linear progress of history is virtually absent. Time is instead primarily seen as static (in philosophies where "real change" is impossible) or cyclical (either in agrarian cultures or in philosophies where the perceived cyclical movements of the stars and planets are dominant in the experience of time). And even if occasionally there is some kind of linear experience of time, it is only perceived as the distance elapsed between the past and the present; there seems to be no spontaneous extrapolation of this movement toward the future (Van der Pot 1985, p. 30). Nomadic cultures on the contrary tend to have another experience of "history," with both a past and a future. The originally nomadic backgrounds of early Judaism are hence often referred to as the source of the linear, unstoppable, and future-oriented experience of time in the three monotheistic religions. Early Christianity was moreover strongly influenced by the idea of an imminent "end of times" which prevailed in the Judaism from which it originated. The apocalyptic vision in Mt 25 (the "final judgment") thereby instilled a sense of urgency and stressed the importance of the very material earthly life.

Even within a linear experience of time, a variety of views existed. Is there a beginning of time (i.e., $t=0$: Big Bang, the moment of creation) or not (i.e., time coming from $-\infty$)? Will time or history come to an end (either physically – the Big Crunch – or at least culturally, as in Teilhard de Chardin's "point Ω," or the "classless society") or will time continue forever (until $+\infty$)? Until recently, scientists even theorized about the possibility of an oscillating universe, with the singularity of a "Big Crunch" immediately leading to a new "Big Bang."

In a culture with a future-oriented vision of time, the idea of (inevitable?) progress can develop: an idea of progress that has, in the Western world, almost self-evidently (except in primitivistic views of culture) been identified with technological growth. The 1972 book "*Limits to Growth*" was one of the first to fundamentally question the possibility of permanent growth.

Besides the progress-oriented vision of time, the development of a positive attitude toward *work* is among the causes mentioned for explaining technological development in the Western world. In Greek philosophy, a negative view on manual work prevailed. In Judaism, work appeared mainly as a "fact of life" which had to be accepted, even if there was always the reminiscence of Gen 3:19, in which labor appears as God's punishment for the original sin. In Christianity, a gradual evolution toward a better acceptance of labor can be found: from the "Ora et Labora" of the Benedictine tradition to the development of a real work ethos (attributed by Max Weber to certain currents in Protestantism). Even without the specific work ethos in itself, the Protestants' belief in the right and the ability of individuals to form their own judgment in religious affairs had its parallel in scientific matters. Van der Pot (1985, pp. 90–91) illustrates the connection between scientific and industrial development and the early Protestantism by pointing out the disproportionate number of religious nonconformists or protestants among entrepreneurs in England and Wales around 1770, the founding members of the *Royal Society for the improvement of natural knowledge* in London in 1660, and the foreign members of the *Académie des Sciences* in Paris between 1666 and 1883. Although one must always be aware of the difficulty in establishing a causal relationship between cultures in general and the currents that are part of these cultures (e.g., is Protestantism a cause or a consequence of the changing times?), these considerations about the rise of Protestantism can help answer the question of why it took about a millennium for that scientific-industrial development to lift off, especially if technological development and our dealing with nature are tributary to Judeo-Christian tradition, and Christianity became a dominant factor in Western culture during the early Middle Ages already.

Confrontation with Other Cultures

Islam is undoubtedly the religious movement which has most kinship with Judaism and Christianity. All three are religions of revelation, having in common many figures and stories in their fundamental texts. The Qur'an (e.g., 7:45 and 15:26) refers to creation in very similar terms as the Jewish and Christian Bibles. Additionally, Avicenna and Averroes are but two of the important philosophers and scientists of the flourishing Persian and Arabic cultures, at the moment of the Middle Ages in the West.

However, the *dominion terrae* idea is far less distinct in Islam. The idea that the earth is Allah's gift to man, and that man is called to rule over nature as Allah's representative, is not unknown to Islam (Van der Pot 1985, p. 501 and p. 1081). But this idea found a strong counterpart in a current in which the eleventh–twelfth century philosopher al-Ghazzali played a major role, who found that "every attempt to take power over the world by science or techniques must be seen as an offense against Allah's omnipotence" (translated from Van der Pot 1985, p. 43). With the idea of "submission" being present in the very meaning of the word "Islam" itself, the distance between man and Allah in the metaphysical triangle (Fig. 23.1) is much larger than in, for example, Christianity (Gauchet 1985, p. 93, see also Cloots 2008, p.15). Allah's overwhelming presence is such that nothing (no form of political power, no form of knowledge) can be seen as "purely secular and divorced from the ultimate goal of human existence" (Van der Pot 1985, pp. 43–44).

A common feature among many Asian philosophies and spiritualities, on the other hand, seems to be the absence of a deity which would be conceived as a person possessing all desirable human qualities on a supereminent level: no overarching, supernatural, omniscient, omnipotent, and willing superrationality. Instead of a separation between the profane and the divine, a sense of harmony and interconnectedness prevails. The idea of opposing and tearing apart the corners of the "metaphysical triangle" would there be perceived as quite artificial. Spiritualities including a form of reincarnation further confirm the idea of a fundamental unity between mankind and nature. Man is not positioning himself against nature but within nature. The aspiration to dominate the world – allegedly so typical for Western cultures – would in *Buddhism* be tempered by the conscience of the "impermanence and insubstantiality of life" (Henning 2002, p. 15), or by the desire to transcend "the illusions of the self" (Cloots 2008, p. 15). With compassion, moderation, and humility as its "Three Jewels," *Daoism* has no place for the idea of human domination either. The ideal human action is *wu wei*: non-coercive activity (compared by Nelson (2004) with Heidegger's *Gelassenheit*). Man is not to impose him/herself upon the world but to live in attunement with it (Rai et al. 2009, p.13).

Although this exploration of Eastern spiritualities is far too short to render their full nuances and significances, the contrast with the Western attitude of rational exploration and manipulation of the world is obvious. The breakthrough of a Western-style industrialization in, for example, contemporary India and China is hence seen by many as a rupture with traditional local values.

The Empirical Turn

Excerpting ideas, intuitions, and logic in religious or philosophical ideologies is one thing, while finding out what people really think may be something different. Minteer and Manning (2000), Manning (2003), Minteer (2007), and de Groot (2010) conducted empirical research on the attitudes of people regarding nature and environment. The Canadians Minteer and Manning identified a range of 17 "types of environmental ethics," brought together in five clusters. On the extreme ends of the scale, there are an anti-environmental attitude (nature is seen as a source of physical threats or of spiritual evil) and radical environmentalism (considering all living things as interconnected, valuable, or carriers of rights). In between these extremes lie attitudes of benign indifference, utilitarian conservation, and the stewardship idea. De Groot's research took place in the Netherlands, France, and Germany. She too started with a set of images of the human/nature relationships, and statistical analysis of the study responses revealed however that it was better to rearrange and slightly redefine the clusters. She came to a subdivision in which the human/nature relationship could be described as "master," "guardian," "partner," and "participant," with "guardianship" being a more ecocentric variant of the traditional "stewardship" idea. It appeared that almost all respondents (91%) agreed with the guardianship image, followed by "partnership" (52%), "participation" (28%), and "mastership" (15%).

One of de Groot's conclusions is thus that the mastership idea, although generally described as being typical for the Western world (and often commented on, like in White's and this chapter), and although discernible in major religious and philosophical theories, is not supported by the majority of the population. In fact, virtually all respondents recognized nature to have some intrinsic value. Yet these views are held by individuals and are not always reflected in the attitudes of organizations and institutions, which often concentrate on economic utility. "The tapestry of our life is, to a large degree, woven by institutions and many of these fail to recognize and exploit the public basis for nature-friendly institutional action" (De Groot 2010, p.120).

Conclusion

Perhaps the turmoil caused by Lynn White's 1967 article was partly due to the accusing tone he used. From a historian, one can expect a descriptive study, starting from his or her reading of the facts, causes, and consequences in the line of history. By translating "roots" or "causes" in terms of "guilt," White struck a normative tone, which made some authors rush to the defense of the accused, even if the factual information gathered by White was little new in itself.

Secondly, even indicating discrete events as causes for a situation can be a risky task; interpreting a millennia-long tradition, with all the currents and evolutions it has undergone, inevitably limps by being selective and constructive at the same time. One can indeed see a thread of activism, anthropocentrism, and disenchantment of nature through the Judeo-Christian tradition. And yet, that same tradition was also associated with moments of awe in front of nature, withdrawal and rest instead of work, and awareness that salvation cannot just be produced but must be received. The same tradition which is linked to progress and activism has also been accused of conservatism and obscurantism. Christianity is the religion of Saint Francis as well as Inquisition; of liberation theology as well as strict ritual fundamentalism. Yet, by its dominant position in Western history, it cannot be denied that Christianity has played a role in the development of the actual society. Gauchet saw modernity and enlightenment as an offspring of Christianity itself, and the industrial revolution is undoubtedly rooted in the same movement of gaining confidence and claiming liberty in religious, political, and economic matters. In Christianity, the imperative to actively take care of others and taking suffering seriously are elements that should prevent it from sliding into either escapism or mere submission (although both tendencies were certainly present at times).

At least in Western Europe, the situation of religions has changed drastically the last few decades. In many countries, traditional Christianity is shrinking, leaving the room for a largely secularized society. In other countries, a revival of religions can be noticed. And the mixture of cultures by migration (as well intra-European as from abroad) is far from stabilized. Finally, the worldwide awareness of globalization, with its political, economic, technological, environmental, and cultural aspects, complicates and intensifies the challenge of investigating and reflecting on the ways cultures influence, adopt, and adapt new situations.

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