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Abdelaziz Bouras · Laurent Veillard
Editors

Industry Integrated Engineering and Computing Education

Advances, Cases, Frameworks, and Toolkits for Implementation

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Foreword

Academia: Dr. Hassan Al-Derham, President of Qatar University, Doha, Qatar

Qatar has set a futuristic vision to transform into innovation- and knowledge-based economy by 2030. The Qatar National Vision 2030 presents a model that articulates the focus on building human capacity with a national mandate to support and strengthen science, technology, engineering, and mathematics (STEM) disciplines. Qatar University has set an ambitious transformation strategy to configure itself as effective contributor to the national vision of Qatar. At the core of the university transformation comes educational model and delivery transformation; engineering and computing education is a core component in this process. One of the major pathways in implementing educational and curricular transformation is organically constructing the needed competencies of industry in engineering and computing education. This book is a scholarly contribution to raise awareness and to initiate further dialogue on the importance of engineering and computing education alignment with industry needs. The book stands as one of the few available recent compilations of advances and studies on the topic, and Qatar University is proud of this seeding contribution. I would like to thank the authors and editors for their contributions and efforts. I am also grateful to the Qatar National Research Funds (QNRF) for funding the project under which this work has been achieved.

Industry: Dr. Mohammed Yousef Al-Mulla, Managing Director and CEO, Qatar Petrochemical Company (QAPCO) Q.P.J.S.C.

It is my pleasure to introduce this new scholarly book on "Engineering and Computing Industry Integrated Education," a much-needed topic to address nowadays. I am personally excited to write this foreword as the book is addressing a global challenge of aligning the educational curricula with national needs, which are faced almost in every country. This is highly important within the current dynamic transformation of the industry, the so-called Industry 4.0. The educational institutions should examine new and relevant education and training opportunities, exposing them to a necessary adaptation to such new era. A continuous dialogue with the industry will be the key to address industry-specific talent challenges and to anticipate and prepare the future skills. The combination of the editors' and authors expertise in both technical and pedagogical fields across different contexts and countries has been ideal to undertake this work. The book has provided a number of international case studies as well as local case studies. Furthermore, the book provided strategic translational perspectives from pedagogy and organizational development for the execution of further socioeconomic impact on engineering schools and curricula. I hope, with this contribution to the general body of research and knowledge advancement, a holistic discourse is initiated, enhancing further developments and implementations of industry needs in engineering and computing education.

Acknowledgments

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Contents

Editors Biographies

Mahmoud Abdulwahed holds BSc, MSc, and PhD in Electrical, Control, and Systems Engineering; he completed his graduate studies in Germany, Sweden, and the UK. His professional and scholarly expertise is in innovation and strategic development, mainly in the higher education industry. His expertise in exploiting systems control and process engineering methods into strategic development and education systems and processes design (e.g., engineering the education or education engineering) is relatively unique, and he is among few globally experts in this area. These translational methods enable effective, accelerated, goal-oriented, and systematic outputs. In scholarship, he has ranked among top 50 scholars globally in the field of engineering education research (EER) in terms of indexed publications number in Scopus (2012–2017 periods). He published 2 books, 1 book chapter, and 60+ peer-reviewed conference and journal articles and developed 40+ institutional reports/frameworks or strategies; his multidisciplinary publications span over the areas of innovation, digital transformation, entrepreneurship, leadership, pedagogy, education design, organizational development, and applied systems theory. He attained several industry funds, academic recognitions/awards, and best papers distinctions from various universities and organizations, as well as fellowships from the University of Technology Sydney, University Science Malaysia, and US Department of State (Ministry of Foreign Affairs). Mahmoud joined Qatar University in Fall 2011 as joint faculty member between College of Engineering and College of

Education and progressed in innovation advisory and strategic development assignments with Engineering Dean's office, the Vice President and Chief Academic Officer Office, and the President Office, where he is currently director of Strategic Initiatives Office and Associate Professor of Engineering.

Abdelaziz Bouras is professor in the Computer Science and Engineering Department of the College of Engineering at Qatar University where he is chairing the Industrial and External Relations Committee. He is also managing the Pre-Award Department at the Office of Research Support at Qatar University. With his team of senior specialists, he manages several initiatives and high-impact collaboration programs, at both international and industrial sides, and contributes to an ambitious governance program for Qatar University, within its Strategy 2030. He also held the ictQatar (ICT Ministry) chair position until September 2016, where he worked on bridging the gap between policy-makers and R&D institutions in Qatar. He led several initiatives on cooperative education and capacity building within the European Commission Erasmus-Mundus program and currently leads the Qatar Foundation Pro-Skima project "PROfessional education development and SKIlls Management – Ontology-Enhanced Workplace Learning" (NPRP7-1883-5-289), in collaboration with the European universities and Qatari stakeholders. He guided around 30 PhD students in ICT and information systems fields. Some of them were co-supervised with the international institutions under joint agreements (from EU, Africa, and Asia). He published more than 150 research papers in referred journals and international conferences and edited several books and two international journals (IJPD, IJPLM). He is also chairing the IFIP International Federation of Information Processing WG5.1, which is holding a yearly international conference on specific enterprise information systems (PLM), and coediting a yearly Springer book. Prof. Bouras is currently member of several committees in Qatar, such as the Ministry of Transport and Communications "Digital Incubation Center" judging board or the Challenge22 projects' reviewing board. He is regularly invited to be part of awards and dissertation juries in several countries.

Laurent Veillard is associate professor at Lumière University Lyon 2, France. After a master's degree in Industrial Chemistry obtained in 1993, he completed a PhD in Education about students' workplace learning in the context of a work-based engineer training course in 2000. He reached the position of associate professor at Lumière University Lyon 2 (France) in 2001 and became a member of the ICAR laboratory, which is characterized by some multidisciplinary research activities on the multimodality of the use of language in some various interactional contexts (workplace, family, educational contexts, etc.). He obtained the "Habilitation à Diriger des Recherches" (HDR) in 2015. His own researches are about the initial vocational education and learning both at secondary and tertiary levels, especially in technical fields like production management, data processing, cars maintenance, etc. He is more precisely interested in the specificities of teaching and learning according to different social contexts (classroom, workshops in school, workplace, etc.), students' transitions between these contexts, and problems of connectivity and integration of different knowledge and learning experiences. He uses some ethnographic approaches combining various types of data: interviews, observations, video recordings, and analyses of written documents. He is co-manager of the ViSA national project which aims at developing and sharing some methodological and technical tools for educational studies using video recordings. He teaches in a technical institute, which is specialized in work-integrated training programs for training middle-level managers in different technical fields. He gives also some teaching courses in different master's programs in the field of vocational and professional education.

Chapter 1
Editorial Perspectives on Industry-Integrated Engineering and Computing Education and Fostering the Socio-Economic Development Role of Engineering and Technology Schools

Mahmoud Abdulwahed, Abdelaziz Bouras, and Laurent Veillard

In both global and regional contexts, the book aims to address critical issues and initiate in-depth debate for engineering and technology education that integrates effectively industry, market, national, and global needs…

Editorial Perspective

Industry-integrated engineering and technology education have been hot topics during the past couple of years (Fitz-Coy et al. 2002; Duffy et al. 2007; Sahama et al. 2008; Ilozor and Kelly 2012; Veillard 2012, 2015; Shin et al. 2013; Bouras et al. 2014; Kovalev et al. 2015; Mutereko and Wedekind 2016; Abdulwahed and Hasna 2017; Wilke and Magenheim 2017; Nickola 2017; Shen et al. 2018; Mardis et al. 2018; Samuel et al. 2018; Gasmi and Bouras 2018; Coşkun et al. 2019; Parsons and MacCallum 2019).

This was driven by continuous complaints of industry and market parties of a lack of engineering and technology graduates possessing the necessary core technical competencies as well as soft skills for adequately fulfilling their professional roles (NRC 2004, 2005; Kerr 2010; Rabl and Hillmer 2012; Abdulwahed et al.

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2013; Itani and Srour 2015; Jackson 2015; Lynch et al. 2015). Some institutions have started to embrace radical and transformative approaches to engineering education and curriculum design driven by recent research findings and pressing national needs, for example, Aalborg University, Georgia Tech., Olin College, and Singapore University of Technology and Design.

When exploring innovations in engineering education, it might be reasonable to start with questions like the following:

– To what extent does an engineering curriculum reflect the industrial, job market, and national and global engineering needs?
– What are the implications of the local engineering job market for localizing the engineering curriculum?
– What are the implications of the national governmental strategic plans for engineering and the engineering curriculum?
– How does an engineering curriculum reflect the local and regional culture?
– What are the challenges faced in integrating industry in engineering education?
– What are the current best practices in embedding industry and contextual needs in the engineering curriculum?
– What are the emerging models of highest potential?

The aforementioned critical questions gain higher amplitude when positioning engineering, technology, and computing colleges and schools as core contributors for national and global innovation and knowledge based economy and society development, or in a shorter terms as catalyst drivers for socio-economic development (Abdulwahed 2017; Abdulwahed and Hasna, 2017).

A natural approach to designing an engineering curriculum needs to start from *understanding roles of engineering curricula in contexts and job market needs, currently and in the future, to produce graduates who best meet industry, market, and national needs* (see Fig. 1.1).

Book Scope

In light of global advances and innovations in engineering education as well as global and regional developments, the book aims to address critical issues relevant to industry-integrated engineering and computing education, such as identifying (1) novel innovations and cases in implementing industry-integrated engineering education and (2) frameworks, models, and toolkits for engineering academics to utilize in implementing industry-integrated engineering education. The book chapters are authored by engineering education academics from North America, Europe, Asia, and the Middle East.

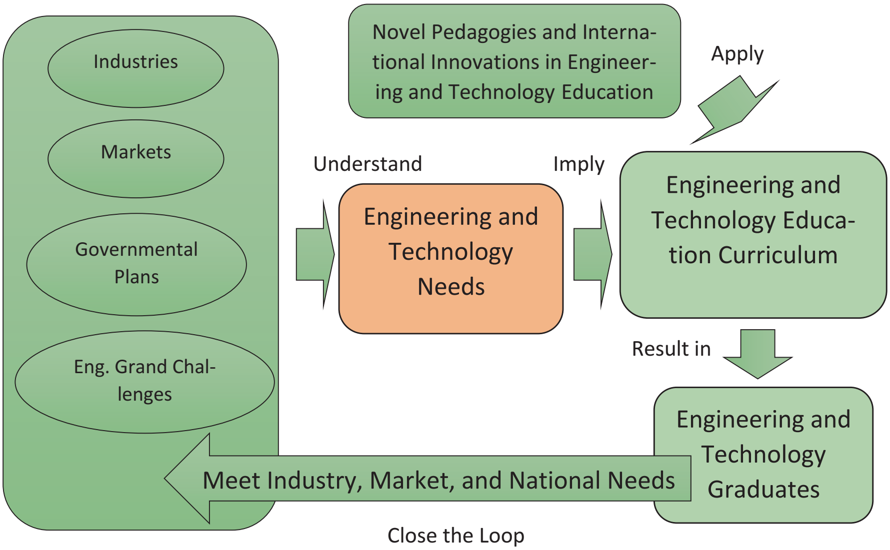

Fig. 1.1 Closing the loop in curriculum design: Optimal curriculum will require thorough understanding of the context to result in graduates who best fit the current and futuristic requirements. This will include understanding competencies needed for industry, market, government, and grand challenges. Considering novel pedagogies and innovations in engineering education will base the design on strong theoretical principles and would embed state-of-the-art educational approaches and methods

Brief Outline of the Book Chapters

Chapter 1 – *Editorial Perspectives on Industry-Integrated Engineering and Computing Education and Fostering the Socio-Economic Development Role of Engineering and Technology Schools:* Editors in this short chapter provide general perspective on the topic of the book and its chapters.

Chapter 2 – *Frameworks for Translational Utilization in Constructing Socio-Economic Needs in Engineering and Computing Schools:* The author provided a translational perspective brining a review of several frameworks and models for the entrepreneurial and socio-economic engagement of universities into the engineering education community and provided a hypothetical implementation case in an engineering school.

Chapter 3 – *Lesson Study Among Engineering Lecturers as a Way to Plan, Implement, and Improve an Industry-Integrated Course:* Authors provided collaborative design and delivery models for implementing industry in introductory engineering courses through focus on sustainability.

Chapter 4 – *Implementing Real-Life Engineering Problems as a Means of Learning in Part-Time Engineering Master's Programmes:* The author provided a case of implementation of a part-time MSc program in Denmark for professional engineers to upgrade their skills. The program is designed using project-based learning for problems in the professional context as a core component.

Chapter 5 – *New Information Technology Patterns Based-Secure BIM Learning Through Education Integrated Engineering System:* The authors provided a model for implementing graduate certificate in BIM with cybersecurity component based on industry needs.

Chapter 6 – *Exploring the Rotational Onboarding Programs for Early-Career Engineers in Practice:* The authors provided an analysis of onboarding programs in the USA and provided key factor requirements of structure; these programs also are utilized as a leadership development platform.

Chapter 7 – *Reverse Engineering and Straightforward Design as Tools to Improve the Teaching of Mechanical Engineering:* The authors provided models for implementing reverse engineering design in an engineering course in Mexico together with a model and procedures for the delivery of the course; project-based learning (PBL) was a core component in the pedagogy delivery.

Chapter 8 – *Teaching Safety, Health, and Environment in Engineering Programs for Millennials – Ethics Is the Basis:* The authors provided a well-rounded professional ethics model development in engineering education in the USA that integrates theory, philosophy, behavioral value, experiential learning, and professional ethic frameworks.

Chapter 9 – *Factors Affecting the Success of IT Workforce Development, a Perspective from Thailand's IT Supervisors and Internship Students:* The authors provided a study and developed an integrated model for preparing IT graduates in Thailand ready for the workplace needs. The model takes into consideration influencing factors, development activities, and the IT worker's learning stages and can be implemented in IT education.

Chapter 10 – *A Collaborative and Interdisciplinary Approach to Bring Closer a Curriculum to Local Employer Needs:* The authors provided a theoretical framework derived from the sociology of curriculum theory for the development of industry-integrated programs, with overview models for proposed MSc programs in Qatar, and also an overview model of an existing undergraduate program in France.

Chapter 11 – *Towards a Holistic Approach of Cybersecurity Capacity Building Through an Innovative Transversal Sandwich Training:* The authors provided a holistic approach for designing interdisciplinary cybersecurity curriculum in France in line with global and EU frameworks and best practice models.

Chapter 12 – *The Toolkit – Pedagogies, Curricular Models, and Cases for Engineering Academics and Schools Implementing Industry-Integrated Engineering Education:* The author provided a toolkit of curricular and pedagogical models for engineering academics to utilize in implementing industry-integrated engineering and computing education, with a particular emphasis on competency-based education.

Conclusions

This book is one of the few available compilations of recent advances in industry-integrated ad computing education. We aim with this edition to contribute in a further systematic approach to emerging international efforts and needs of industry and engineering schools to align curricula and encourage educational model innovations for fostering this alignment. There are several anticipated benefits of such fostering such as but not limited to: (1) economical optimization by smoothening the onboarding process of recent engineering graduates into the job market as quickly as possible and with the minimal training needs, (2) organic approach for fostering collaboration between members in industry and engineering academia through the established operational models and platforms for fostering industry-integrated engineering education, (3) acceleration of innovation by blurring the boundaries between the pragmatism of industry and the scientific excellence of universities, and (4) higher levels of student satisfaction, success, retention, and engagement in engineering education. We hope that this work would be followed by periodic future editions, and seed for new ideas or platforms for further shared experiences globally in the field of engineering and computing industry-integrated education.

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Chapter 2
Frameworks for Translational Utilization in Constructing Socio-Economic Needs in Engineering and Computing Schools

Mahmoud Abdulwahed

Introduction

In this chapter, we shed light on frameworks utilized for integrating academia with socio-economic context and needs (ACEEU 2016; Davey et al. 2014; NCEE 2013; OECD 2012; OIE 2013; Gibb et al. 2013). These are rather generic and have been utilized outside the engineering education and engineering institutions in most. The main idea is to have a global perspective on the topic from outside the narrow engineering field domain and stimulate a translational thinking of adoptions of such models into engineering organizational and curricular development. We also shed a light on some of the best pedagogical models that can be utilized in engineering schools to foster socio-economic engagement. We have particular focus in this chapter on socio-economic and entrepreneurial transformation models since engineering and technological innovations are one of the top major drivers of economic development in innovation- and knowledge-based economies (Abdulwahed and Hasna 2017; Abdulwahed 2017). Subsequently, engineering schools that aim to play a leading role in driving economic development would need to transform, re-adjust, and embrace an entrepreneurial spirit which will be reflected in their organizational and curricular structures. A corner stone in such transformations is strong integration with industry and market needs, and producing fit to market graduates who are also leaders of future economic development driven by innovation and technology.

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Translational Perspectives on Organizational and Institutional Frameworks

Entrepreneurial and Engaged University Accreditation Standards

The Accreditation Council for Entrepreneurial and Engaged Universities (ACEEU 2016) has developed a variety of standards that enable to describe and evaluate engaged and entrepreneurial universities. The standards are structured according to the following five dimensions which build ACEEU's guiding accreditation framework:

– Orientation and strategy
– People and organizational capacity
– Drivers and enablers
– Education, research, and third-stream activities
– Innovation and impact

Within each of the five dimensions, there are three standards which differentiate the activities and attainments expected of either the engaged or entrepreneurial university. Several standards were derived from the European Union–Organisation for Economic Co-operation and Development (EU-OECD) framework.

Orientation and strategy (1) Institutional commitment: The university has made a public and strategic commitment to entrepreneurship; (2) Institutional commitment: The university has made a public and strategic commitment to entrepreneurship; (3) Financial planning: The university has a sustainable commitment to entrepreneurship which can be identified by commercial activities, financial income, and expenditure plans.

People and organizational capacity (1) Leadership: The university's values and its approaches to leadership combine to foster entrepreneurship, including risk taking; (2) Staff profiles: The university manages its profile of academic and non-academic staff to meet the current and future demands of the entrepreneurship; (3) Incentives and rewards: The university has a coherent system of incentives and rewards to undertake and support entrepreneurship activities.

Drivers and enablers (1) Culture: The university promotes a culture conducive to thinking and acting entrepreneurially; (2) Internal support structure: The university's internal support services and facilities enable individuals to progress through the stages of their entrepreneurship journey; (3) Service alignment: The university enhances its internal support structures by brokering access to external services, thus providing a comprehensive support system for entrepreneurship.

Education, research, and third-stream activities (1) Education: The university provides a variety of opportunities for students to improve their entrepreneurial knowledge, skills, and actions, and thus supports a wide range of graduate careers, including intrapreneurship, self-employment, and entrepreneurship; (2) Research: The university's research aims to support the creation of economic impacts and also to contribute to the field of entrepreneurship; (3) Third-mission activities: The university undertakes a wide range of external commercial activities.

Innovation and Impact (1) Continuous improvement: The institution is achieving improvement in entrepreneurship by regularly evaluating its performance against targets; (2) Influence within the ecosystem: The university is an influential stakeholder in the entrepreneurship ecosystem; (3) Impact: The university generates a wide range of benefits through entrepreneurship and is working toward greater economic impacts in the region.

EntreComp – Entrepreneurial Competency Framework for Universities

EntreComp was developed in 2016 by the Joint Research Centre (JRC) of the European Commission on behalf of the Directorate General for Employment, Social Affairs, and Inclusion (DG EMPL) (see Bacigalupo et al. 2016). The origin of this work goes back to 2006 when the European Union proposed eight key competences for lifelong learning, one of which was a "sense of initiative and entrepreneurship." The *Entrepreneurship Competence Framework*, also known as EntreComp, offers a tool to improve the entrepreneurial capacity of European citizens and organizations. The framework aims to build consensus around a common understanding of entrepreneurship competence by defining 3 competence areas, a list of 15 competences, learning outcomes and proficiency levels, which current and future initiatives can refer to. The EntreComp Framework is made up of three competence areas: "ideas and opportunities," "resources," and "into action." Each area includes five competences, which, together, are the building blocks of entrepreneurship as a competence. The framework develops the 15 competences along an 8-level progression model. Also, it provides a comprehensive list of 442 learning outcomes, which offers inspiration and insight for those designing interventions from different educational contexts and domains of application. The EntreComp conceptual model is shown in Fig. 2.1 (Bacigalupo et al. 2016), and the 15 competencies composing the model are: (1) spotting opportunities, (2) creativity, (3) vision, (4) valuing ideas, (5) ethical and sustainable thinking, (6) learning through experience, (7) working with others, (8) coping with ambiguity, uncertainty, and risk, (9) planning and management, (10) taking the initiative, (11) mobilizing others, (12) financial and economic literacy, (13) mobilizing resources, (14) motivation and preference, and (15) self-awareness and self-efficiency.

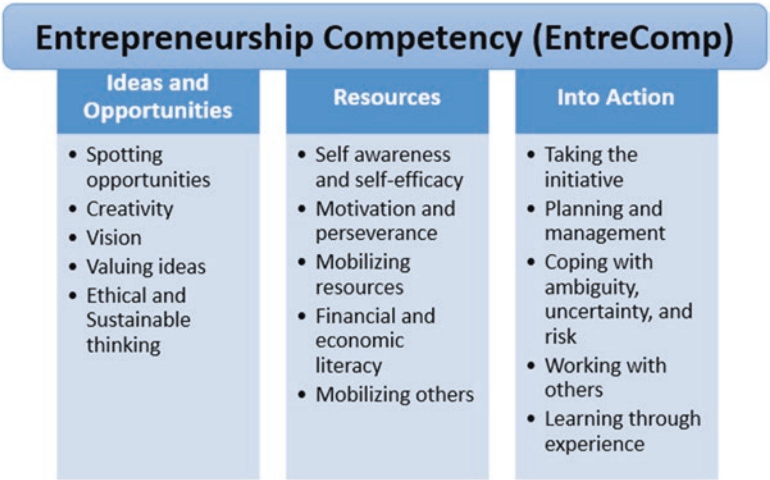

Fig. 2.1 Conceptual model of the EU EntreComp framework

OECD Entrepreneurial University Framework

The EU-OECD entrepreneurial university framework was developed in 2011–2012 to offer European Universities a generic and structured approach to assess their entrepreneurial capacity and develop it further (OECD 2012); the initial framework was later on refined under an EU-funded project and branded as HEInnovate (Gibb et al. 2013; Hofer and Kaffka 2018). Characterizing factors (around 40 factors) of entrepreneurial universities have been clustered into seven main dimensions (based on the HEInnovate version):

1. Leadership and governance
2. Organizational capacity, funding, people, and incentives
3. Entrepreneurship development in teaching and learning
4. Support pathways for entrepreneurs
5. University–business–government collaboration and knowledge exchange
6. The entrepreneurial university as an internationalized institution
7. Measuring the impact of the entrepreneurial university

Leadership and Governance (1) Entrepreneurship is a major part of the higher education institution's (HEI) strategy. (2) There is commitment at a high level to implementing the entrepreneurial agenda. (3) There is a model in place for coordinating and integrating entrepreneurial activities across the HEI. (4) The HEI encourages and supports faculties and units to act entrepreneurially. (5) The HEI is a driving force for entrepreneurship and innovation in regional, social, and community development.

Organizational Capacity – Funding, People, and Incentives (1) Entrepreneurial objectives are supported by a wide range of sustainable funding and investment sources. (2) The HEI has the capacity and culture to build new relationships and synergies across the institution. (3) The HEI is open to engaging and recruiting individuals with entrepreneurial attitudes, behavior, and experience. (4) The HEI invests in staff development to support its entrepreneurial agenda. (5) Incentives and rewards are given to staff who actively support the entrepreneurial agenda.

Entrepreneurial Teaching and Learning (1) The HEI provides diverse formal learning opportunities to develop entrepreneurial mindsets and skills. (2) The HEI provides diverse informal learning opportunities and experiences to stimulate the development of entrepreneurial mindsets and skills. (3) The HEI validates entrepreneurial learning outcomes which drives the design and execution of the entrepreneurial curriculum. (4) The HEI co-designs and delivers the curriculum with external stakeholders. (5) Results of entrepreneurship research are integrated into the entrepreneurial education offer.

Preparing and Supporting Pathways for Entrepreneurs (1) The HEI increases awareness of the value of entrepreneurship and stimulates the entrepreneurial intentions of students, graduates, and staff to start-up a business or venture. (2) The HEI supports its students, graduates, and staff to move from idea generation to business creation. (3) Training is offered to assist students, graduates, and staff in starting, running, and growing a business. (4) Mentoring and other forms of personal development are offered by experienced individuals from academia or industry. (5) The HEI facilitates access to financing for its entrepreneurs. (6) The HEI offers or facilitates access to business incubation.

Knowledge Exchange and Collaboration (1) The HEI is committed to collaboration and knowledge exchange with industry, the public sector, and society. (2) The HEI demonstrates active involvement in partnerships and relationships with a wide range of stakeholders. (3) The HEI has strong links with incubators, science parks, and other external initiatives. (4) The HEI provides opportunities for staff and students to take part in innovative activities with business/the external environment. (5) The HEI integrates research, education, and industry (wider community) activities to exploit new knowledge.

The Internationalized Institution (1) Internationalization is an integral part of the HEI's entrepreneurial agenda. (2) The HEI explicitly supports the international mobility of its staff and students. (3) The HEI seeks and attracts international and entrepreneurial staff. (4) International perspectives are reflected in the HEI's approach to teaching. (5) The international dimension is reflected in the HEI's approach to research.

Measuring Impact (1) The HEI regularly assesses the impact of its entrepreneurial agenda. (2) The HEI regularly assesses how its personnel and resources support its entrepreneurial agenda. (3) The HEI regularly assesses entrepreneurial teaching and learning across the institution. (4) The HEI regularly assesses the impact of start-up support. (5) The HEI regularly assesses knowledge exchange and collaboration. (6) The HEI regularly assesses the institution's international activities in relation to its entrepreneurial agenda.

UK National Center for Entrepreneurship in Education (NCEE) Framework

The NCEE plays a leading role in entrepreneurial organizational change in UK universities. NCEE co-manages leaders program for UK universities senior leadership level to enable them undertaking necessary organizational change strategies for entrepreneurial institutional change. The NCEE developed a framework for entrepreneurial universities composed of five dimensions (Coyle et al. 2013):

1. Mission, governance, and strategy
2. Stakeholders engagement
3. Entrepreneurship education
4. Internationalization
5. Knowledge transfer, exchange, and support

Under each of these dimensions there is a number of factors, and a total of 108 factors are composing the UK-NCEE framework. A scorecard form for the assessment of all factors is provided in the framework (Coyle et al. 2013). The scorecard on the following pages embraces all of the issues associated with a strategic leadership approach to embedding enterprise and entrepreneurship in the university. It can be used for a comprehensive analysis of the university or for a more focused review of a number of key areas of interest to readers and exploration of areas of potential synergy.

The Innovative and Entrepreneurial University Framework, US Department of Commerce

This framework emerged from a comprehensive work of the office of innovation and entrepreneurship (OIS), Department of State, USA (Case et al. 2014). The framework was a result of a study that included 142 major universities, and it organized 5 major dimensions for innovation alliances for universities:

1. Promoting students' innovation and entrepreneurship
2. Encouraging faculty innovation and entrepreneurship
3. Actively supporting the university technology transfer function

4. Facilitating university–industry collaboration
5. Engaging with regional and local economic development efforts

For each of these dimensions, university activities were clustered into strategies, and details onto these strategies are described below.

Promoting students' innovation and entrepreneurship (1) Offering courses and degrees on innovation and entrepreneurship, (2) focusing on experiential learning and augmenting it with entrepreneurial activities, (3) increasing students' competitions, (4) offering entrepreneurial and innovation collaboration spaces (ideation, maker-spaces, fablabs, design studios, learning spaces, etc.), and (5) increasing entrepreneurial education and training in vocational education.

Encouraging faculty innovation and entrepreneurship (1) Change faculty culture toward focus on innovation and entrepreneurship (hiring, policies, orientation, etc.), (2) reward faculty innovation and entrepreneurship, (3) support faculty collaboration with community and industry, and (4) engage industry with faculty outputs.

Actively supporting the university technology transfer function (1) Reduce technology transfer barriers, (2) expand levels of support for technology transfer offices, (3) protect intellectual property, (4) offer funds to more R&D outcomes into commercialized output, and (5) cluster into regional technology transfer offices.

Facilitating university–industry collaboration (1) Facilitate sharing resources and knowledge, (2) develop venture parks to facilitate startups and industry access to university assets and vice versa, and (3) workout smooth and flexible joint IP and royalties management.

For each of these dimensions, Case et al. (2014) enumerate a number of best practices, examples of these will be provided later on in this chapter.

The University–Business Cooperation (UBC) Framework

The UBC was a result of the largest scale study on collaboration between academia and sectors of government, industry and employers, and societal system enterprises (referred to collectively as "business"). The study covered all countries of the European Economic Area (EEA), which included 33 countries and 6000+ samples using a mixed method approach associated with secondary reviews and comprehensive case analysis from across Europe. UBC was defined as "all types of direct and indirect, personal and non-personal interactions between Higher Education Institutions (HEIs), and business for reciprocal and mutual benefits" (Davey et al. 2011). UBC results/outcomes were defined beyond the creation of patents, license, and research contracts. In total, UBC was defined to occur in eight major areas:

– R&D collaboration
– Mobility of academics
– Mobility of students
– Commercialization of R&D results
– Curriculum development and delivery
– Lifelong learning
– Entrepreneurship
– Management

The study resulted in a systemic strategic and implementation framework for enhancing UBC, and the framework is adopted later on in this document for CENG with slight modifications in terminologies for focus on engineering and technology. *The term "Business" in the UBC framework refers to all potential interactions and transactions (mutual way) between HEIs and industry, government, and social enterprises/stakeholders* (Davey et al. 2011); *majority of UBC identified in the study took place within the engineering, science, and technology domains*.

The UBC has its grass roots in the triple-helix model from Stanford (originated early in 2000) that describes the triple interaction between academia-industry/business-government as the foundational driver of socio-economic development.

Translational Implications on Engineering Schools and Engineering Education

The aforementioned frameworks can provide significantly mature and useful toolkits for engineering schools for implementing comprehensive socio-economic engagement schemes whether institutional, curricular, or extracurricular. All these frameworks provide a structured standards in which engineering schools can work around to transform into actively socio-economic driver of their contextual ecosystem. Most if not all of the aforementioned frameworks have education as a core component to transform. The OECD, ACEEU, and UBC provide probably the most comprehensive framework to adopt, adapt, and extend in engineering schools. As the concept of entrepreneurial transformation in engineering schools is relatively new, these frameworks enable a relatively smoother execution.

Hypothetical Case of Implementing Entrepreneurial Transformation of an Engineering School with a Standardized Framework

In this section, we will choose one of the aforementioned frameworks and demonstrate how one of the engineering schools could proceed in socio-economic engagement transformation (or entrepreneurial transformation) using such a framework as a tool. For instance, the EU OECD/HEInnovate or ACEEU are two of the most comprehensive frameworks, for showing a case lets adopt the EU OECD/HEInnovate framework of entrepreneurial universities and proceed in listing a number of recommendations for implementations in engineering schools for some of the most important standards of EU OECD/HEInnovate framework.

Leadership and Governance Dimension

Standard 1 – Entrepreneurship Is a Major Part of the Institute Strategy

In implementing this standard, engineering schools should see themselves as entrepreneurial organizations and environments, and entrepreneurial agenda should be shaped on the strategy level of the engineering schools. Ideally, below are some of the recommendations to implement this standard in engineering schools:

– Entrepreneurship is emphasized in the vision and mission of the engineering school
– The strategy of the engineering school has specific objectives related to entrepreneurship with measurable performance indicators

Standard 2 – There Is Commitment at a High Level to Implementing the Entrepreneurial Agenda

In implementing this standard, commitment to the strategic entrepreneurial directions expressed in the engineering school vision, mission, and strategy should be embraced on a high level. Examples of implementing such commitment are:

– The strategic entrepreneurial agenda of the engineering school is well communicated and understood by the school community
– There is a dedicated role, on a dean's office level for instance (e.g., associate dean or director), for implementing the entrepreneurial agenda in the engineering school
– There is a periodic re-visit, for example, reflection on progress and re-updates, of the entrepreneurial strategy of the engineering school on high management and leadership level (e.g., dean and heads of departments)

Standard 3 – There Is a Model in Place for Coordinating and Integrating Entrepreneurial Activities across the Institution

In implementing this standard, the engineering school will develop a suitable model for coordinating and integrating entrepreneurial activities within the school and in connection with the university and local entrepreneurial ecosystem. Such an operational model will need to take benefit from existing relationships, coordinate across departments and research centers, and minimize any duplication of work. Examples of implementation of such models are:

- Departments or centers for technology innovation and entrepreneurship are established
- Engineering school level committee or taskforce on “technology entrepreneurship steering committee” is managed by the dean’s office

The Institution Encourages and Supports Units to Act Entrepreneurially

In implementing this standard, engineering schools will aim to reduce bureaucratic and barriers to its units for acting on the entrepreneurial agenda. Examples of implementation of this standard are:

- Accelerated approval chain structure for entrepreneurial initiatives
- Encouragement of calculated risk-taking by units
- Policies in place maximizing autonomy and ownership of entrepreneurial initiatives
- Job description and personnel specifications including entrepreneurial leadership characters, e.g., risk taking, initiation, etc.

The Institute Is a Driving Force for Entrepreneurship and Innovation in Regional, Social, and Community Development

In implementing this standard, engineering schools should be aligned and actively engaged with the external environment (in the university ecosystem, as well as the local ecosystem). Examples of implementing this standard are:

- Providing laboratory and testing facilities to others from outside the university
- Providing services for local technology and digital startups
- Co-forming or participating in local and regional technology innovation clusters
- Establishing joint technology innovation and product development centers with local industry
- Participating in technology development tenders for local and regional projects

Organizational Capacity – Funding, People, and Incentive Dimension

Entrepreneurial Objectives Are Supported by a Wide Range of Sustainable Funding Sources

In implementing this standard, engineering schools will aim in their financial strategies and operational plans to diversify revenue and income, and not solely rely on public or university funding. Examples of implementing this standard are:

– Charge of fees for using the school labs by external entities
– Establishing a consulting arm based on the school expertise
– Offering paid lifelong learning streams for engineering professionals in niche areas relevant to the local ecosystem needs
– Re-investing external attained funds

The Institution Has a Sustainable Financial Strategy in Place to Support Entrepreneurial Development

In implementing this standard, engineering schools will have dedicated adequate resources to allocate for entrepreneurial activities in their financial plans and annual budgets. Examples on implementing this standard include:

– Entrepreneurial activities and needs are budgeted across chapters of the school annual budget wherever relevant
– Financial plans and budget requests of entrepreneurial activities are put on high priority when negotiating budgets

The Institution Has the Capacity and Culture to Build New Relationships and Synergies among Internal Stakeholders

In implementing this standard, engineering schools will have the ability to bring their internal stakeholders including faculty, administrators, research, staff, and students to work together on executing their entrepreneurial strategy and agenda. The engineering school will need to break boundaries and silos, and in particular support interdisciplinarity across departments, research centers, and research working groups. Examples of implementing this standards are:

– Establishing cross-departmental interdisciplinary working groups aligned to local ecosystem grand challenges
– Offering formal and informal spaces (workspace, learning space, meeting space, ideation space) for faculty and/or students to interact and exchange ideas around the entrepreneurial agenda
– Establishing interdisciplinary innovation and entrepreneurial student clubs (from students cross different departments)
– Implementing rewards for encouraging interdisciplinary work
– Developing engineering interdisciplinary courses taught by cross-department faculty members and implementing interdisciplinary students’ projects in such courses
– Encouraging interdisciplinary theses and graduation projects

The Institution Is Open to Engaging and Recruiting Individuals with Entrepreneurial Attitudes, Behavior, and Experience

In implementing this standard, engineering schools will have a structured approach to the recruitment of future faculty and personnel that are able to support its entrepreneurial agenda. Examples of implementing this standard are:

– Job description of new faculty contains entrepreneurial functions, competencies, and/or experiences
– Engagement in brining other personnel with entrepreneurial orientation, such as guest lecturers and alumni
– Establishing schemes such as entrepreneur in residence, or adjunct faculty from industry.

The Institute Invests in Staff Development to Support its Entrepreneurial Agenda

In implementing this standard, engineering schools will have structured programs and a system in place for upskilling its staff and faculty competencies to meet the requirements of the fast changing competency needs for implementing their entrepreneurial agenda. Examples of implementing this standard are:

– Establishing formal policies for career and professional development of staff and faculty that address the needs of entrepreneurial competency and experiences development
– Implementing entrepreneurial professional development programs for faculty and staff
– Attracting well-established entrepreneurial faculty and experts for long or short assignments and facilitating knowledge transfer with existing school faculty and staff

Incentives and Rewards Are Given to Staff Who Actively Support the Entrepreneurial Agenda

In implementing this standard, engineering schools will have a structured incentive system in place to encourage and reward faculty and staff to be more actively engaged in their entrepreneurial agenda. Examples of implementing this standard are:

– Sabbaticals focused on innovation and entrepreneurship
– Joint appointments with industry
– Promotion criteria to include entrepreneurial activities
– Office and laboratory spaces for conducting entrepreneurial activities
– Part-time workload allowance for faculty engaged in building startups

Entrepreneurial Teaching and Learning

The Institute Provides Diverse Formal Learning Opportunities to Entrepreneurship

In implementing this standard, engineering schools will implement structured formal entrepreneurship education in their curriculum. Examples are:

- One mandatory general engineering course on innovation and entrepreneurship
- Minor or major degree (BSc, MSc, or PhD) in technology innovation and entrepreneurship
- Entrepreneurial projects (embedded in courses, or as graduation project) with tech. Startup potential outputs
- Embedding entrepreneurial and innovation competencies in an integrated manner across different courses in the engineering curriculum

The Institute Provides Diverse Informal Learning Opportunities and Experiences to Stimulate the Development of Entrepreneurial Mindsets and Skills

In implementing this standard, engineering schools will implement structured informal entrepreneurship education in their curriculum. Examples are:

- Engineering students' clubs in innovation and entrepreneurship
- Active engineering social entrepreneurship volunteering pathways for engineering students and faculty
- Entrepreneurial training programs, workshops, events, seminars, etc., for engineering students
- Innovation and entrepreneurship competitions, awards, exhibitions, etc.

Preparing and Supporting Pathways for Entrepreneurs

The Institute Increases Awareness of the Value of Entrepreneurship and Stimulates the Entrepreneurial Intentions of Students, Graduates, and Staff to Start a Business or Venture

In implementing this standard, engineering schools will implement structured awareness and culture change entrepreneurship activities for their faculty and staff. Examples are:

- Engineering school entrepreneurship and innovation festival (with faculty and staff participation)
- Engineering school motto and brand with focus on entrepreneurship embedded in it

- Periodic innovation and entrepreneurship newsletter from the dean's office.
- Celebrating faculty and staff entrepreneurial achievements across the engineering school

The Institute Supports its Students, Graduates, and Staff to Move from Idea Generation to Business Creation

In implementing this standard, engineering schools will develop structured and well-integrated idea-to-business activities for their faculty, staff, and students. Examples are:

- Ideation brainstorming sessions, activities, and design studios
- Incubation programs and facilities, or integration with existing incubation assets in the university or the local ecosystem
- Acceleration programs and facilities, or integration with existing acceleration assets in the university or the local ecosystem
- Seed funds or facilitation of seed fund acquisition for business startups
- Facilitation of other professional services, such as legal advises

Knowledge Exchange and Collaboration

The Institute Is Committed to Collaboration and Knowledge Exchange with Industry, the Public Sector, and Society

In implementing this standard, engineering schools will develop structured approaches for collaboration and technology and knowledge exchange with industry. Examples are:

- Technology and knowledge exchange are integral parts of the engineering school policy, which in its turn details how relationships with the industry and government are formulated and operated
- The engineering school provides support mechanisms for coordinating knowledge exchange with industry, for example, industry liaison officer, joint steering committees with industry, etc.

The Institute Integrates Research, Education, and Industry (Wider Community) Activities to Exploit New Knowledge

In implementing this standard, engineering schools will develop structured approaches to actively integrate with industry and government in research, education, and service. Examples are:

– Internships are part of the curriculum
– Industry chairs are appointed jointly between the engineering school and the industry
– Collaborative research projects are conducted with industry
– Entrepreneurial outputs of the engineering schools are exploited actively to the commercial and industry partners in the ecosystem

Conclusions

In this chapter, we provided a translational perspective on frameworks and models for higher education institutional socio-economic engagement; most of these were developed on the level of a university as the institute. As the role of engineering and technology is crucial in the socio-economic development of modern twenty-first-century societies, engineering schools would need to adapt in their organizational structure, operational models, and curricular delivery to maximize their impact and engagement with the socio-economic ecosystem (e.g., society and industry needs). This chapter provides a hypothetical case of embracing one of these frameworks, the EU OECD/HEInnovate framework by an engineering school, and provides some tips on possible implementations for a number of standards under this framework. It is hoped that this work will stimulate further discourse around the concept of the "Entrepreneurial Engineering College" or the "Socio-economic Engaged Engineering College" among the engineering education academics and leaders, and urge into further in-depth developments of such concepts in engineering schools using standardized approaches.

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Chapter 3
Lesson Study Among Engineering Lecturers as a Way to Plan, Implement, and Improve an Industry-Integrated Course

Khairiyah Mohd-Yusof, Fatin Aliah Phang, Aziatul Niza Sadikin, Zaki Yamani Zakaria, Siti Hajjar Che Man, and Mohd. Kamaruddin Abd. Hamid

Background

Often teaching and learning in engineering education at the higher learning institutes is a lonely journey as most academic staff do not interact with their peers to improve their teaching and learning. Usually, they do not discuss ways to improve teaching and learning nor do they enter their peers' classes to learn from each other. In a relatively traditional teaching approach, an academic staff is responsible for supervising a particular subject or lesson throughout the semester. The teaching plan, its practice, and the course assessment and evaluation are carried out by the same individual academic staff. Individual teaching also means the teaching process is not critically reflected, hence hindering the continuous improvement process in teaching. In the case where the course is conducted in multiple sections, individual teaching resulted in unsynchronized and standardized teaching, learning activities as well as student's assessment. In addition, most lecturers are not trained to study their own teaching and student learning (Cerbin and Kopp 2006). They rarely observe lessons and have little opportunity to learn about their students' learning and thinking. Currently, teaching and learning activities and assessment in preparing engineering graduates for the required outcomes are becoming more complex, hence demanding more effort from individual academic staff (Mohd-Yusof et al. 2015). However, career development needs for academic staff normally push time allocation for preparing to teach to a minimal, overwhelming many of them in trying to keep up with the

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requirements that must be implemented in their classes. Lecturers find it challenging to participate in professional development that allow them to be involved in activities to examine their own teaching and determine the impact of instruction on student understanding (Cerbin and Kopp 2006).

In the twenty-first century, teaching and learning in engineering requires immense efforts from the academic staff. Teaching profession should be social (Chenault 2017). There are many benefits for faculty collaborations in teaching and learning to improve the Scholarship of Teaching and Learning (Wood and Cajkler 2017). This is especially true when integrating industry, community, or real-world experiences into the curriculum because it requires a lot of preparations from academic staff. Working together in a team of academics will ease the burden, as well as generate better ideas and implementation.

One of the ways for professional development in teaching and learning in higher education is through Lesson Study. This method, which originated from Japan (Norton 2018), is for teachers to collaborate and learn from each other in preparing classroom lessons. It focuses on the joint study of lessons through "observation of live classroom lessons by a group of teachers who collect data on teaching and learning and collaboratively analyse them" (Lewis et al. 2006, p. 3). Lesson Study is practiced extensively among school teachers as a part of their teaching development through reflective and collaborative efforts (Wong and Phang 2017).

Figure 3.1 shows a model of Lesson Study that can be implemented in teaching and learning. The model starts with studying the curriculum, formulating goals, and defining the problems in teaching and learning among a group of educators on one subject. After the goals are set, the next step is to plan the lesson and then to conduct the lessons together with observation or data collection. After the data is analyzed, the educators will reflect on their teaching and may revise the lesson. They may also share the results to interested parties outside of the Lesson Study group. Lewis and Hurd (2011) also introduced another similar model as in Fig. 3.2. Therefore, in this study, the steps to conduct our Lesson Study are:

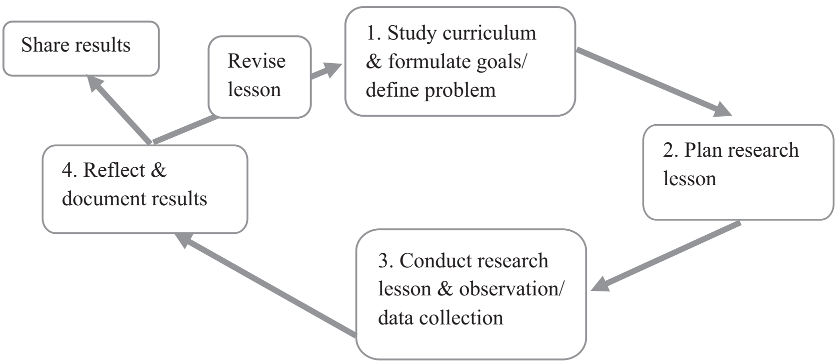

Fig. 3.1 Model of Lesson Study by Wong and Phang (2017)

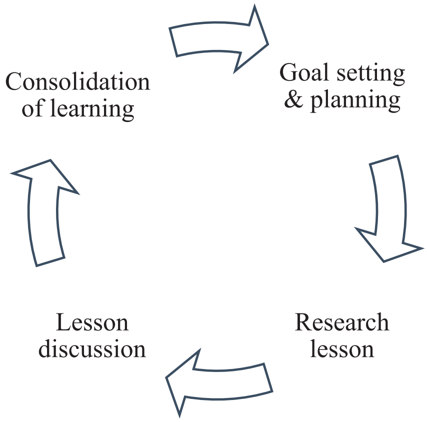

Fig. 3.2 Model of Lesson Study by Lewis and Hurd (2011)

1. Formulating learning goals.
2. Planning of lecturers' guide.
3. Teaching and observing.
4. Analyzing the evidence and improving the lessons.

Previous studies (Ylonen and Norwich 2013) have shown the effectiveness of Lesson Study in improving school teachers' pedagogical content knowledge (Cheah and Lim 2010), making teachers more prepared for their lessons (Ong et al. 2010) and coping with changes of new curriculum (Tan and Nashon 2017). Studies (Cheah and Lim 2010; Tan and Nashon 2017) also found that Lesson Study is also a way to help teachers to shift toward a student-centered learning approach. At higher learning institutes, it was found that Lesson Study promotes reform-based pedagogical practices, reflective teaching practices, awareness of student thinking, and misconceptions and collaboration with colleagues (Demir et al. 2013). Lesson Study could be particularly useful in developing the idea of teaching as a community effort rather than an individual endeavor (Christiansen et al. 2007). The authors further pointed out that there is a need for academic staff in higher education to share not only knowledge related to pedagogical principles but also experiences related to creating the best learning instruction for students. Instructors need to understand how their students learn in order to provide effective instruction. Cerbin and Kopp (2006) assert that Lesson Study provides opportunities for instructors to work on significant issues and ideas related to the teaching and learning process in the classroom. Thus, they can develop a shared language and common meanings because instructors observe and discuss the same problem in the same context over an extended period. Furthermore, Cerbin and Kopp (2006) pointed out that although instructors design a single lesson, what they learn from the experience could be applied to other courses. Therefore, the aim of Lesson Study is not merely to produce a well-crafted lesson but also to improve the Scholarship of Teaching and Learning at the higher learning institutes.

Recently, Lesson Study has gained increasing attention in the higher education sector. In this study, Lesson Study is applied among a group of chemical engineering lecturers conducting an undergraduate engineering course, "Introduction to Engineering (ITE)." The course has a sustainable development-themed real problem, which includes partnership with local government authorities, industries, or non-governmental organizations. This chapter provides a framework on how to practice Lesson Study to teach an engineering course that involves outside organization participation, especially when many different sections of students are involved. This can become a good practice to mentor new and inexperienced lecturers. This chapter presents how Lesson Study was conducted so it can be implemented by other engineering educators along with the reflections of the lecturers involved in this study.

Introduction to Engineering (ITE) Course

The "Introduction to Engineering" (ITE) course is a 3-credit hour course for first-year chemical engineering students, which was first introduced in 2005. The course is designed to have a supportive student-centered learning environment that allow students to develop important skills to prepare them to learn engineering in the university, as well as stimulate their interest in the field. The course aims to help students understand the importance of engineering in everyday and professional context and the need for good engineers especially in facing up to the challenges of the twenty-first century.

Taught over 14 weeks in 1 semester, there are 30–40 students in a class, in 3–4 sections, facilitated by 2 academic staff teaching in a team per section. Around 100–160 students take the course in the first semester every year, distributed between the sections based on their gender and race.

Various student-centered teaching and learning approaches, such as cooperative learning (CL), cooperative problem-based learning (CPBL), flipped classroom, and case study approach, were used to support students in attaining the course outcomes, which includes knowledge and skills outcomes such as communication skills and lifelong learning skills. According to Grant and Dickson (2006), professional skills are more likely to be developed by students if the skills are embedded within the curriculum, rather than taught in separate classes.

Elements of CL are used in dividing students in each class into teams of three to five students. The teams are formed based on careful consideration of a predetermined criteria to ensure heterogeneous groups: gender, ethnicity, English proficiency, and geographical origin. Heterogeneous groups promote more diverse thinking and provide opportunities for students to develop interpersonal and teamworking skills in working with team members with different characteristics. At the beginning of the course, the students went through several ice-breaking activities to help them bond with their team members. These include developing team identity through choosing suitable names for the teams, determining team goals, designing teams' logos as well as agreeing on the teams' regulations and putting them in a team contract in which each team member signs to signify commitment to the team rules.

Since the course is conducted in a highly student-centered environment, two lecturers co-teach each of the ITE sections to provide closer guidance and facilitation for the students during the class sessions. This also reduced the demanding workload of preparation and assessment in the course, allowing the lecturers involved to be creative in improving the conduct of the course and inviting stakeholders such as industries and local authorities to be involved in the course in various ways.

The ITE course basically covers four main topics: engineering overview (EO), sustainable development (SD), basic engineering calculations (BEC), and engineering ethics (EE). Figure 3.3 provides the visual representation of the main topics with the corresponding methods used to teach them. The teaching modes of the topics are summarized in Table 3.1.

For the engineering overview topic, students are divided into small teams of three to five members to learn about engineering and engineering process, as well as specific topics on engineering given to different teams, such as engineering problem-solving, engineering ethics, preparation needed to be a future engineer, being a professional engineer, etc., through an assignment designed based on cooperative learning. They are required to find information and interview practicing engineers to answer "What is engineering?" and the specific topic assigned to their team. The task is to be completed in 10 days, thus inducing them to plan and work together swiftly to complete a simple report and present and make a video on their findings.

Students learn about sustainable development (SD) through a problem that presents issues related to an SD theme. The problem, such as the plastic waste problem, sustainable fashion, energy sustainability, water conservation, low-carbon society, etc., is changed every semester. To solve the problem, students learn about the definition and the declarations on sustainable development, current issues and initiatives

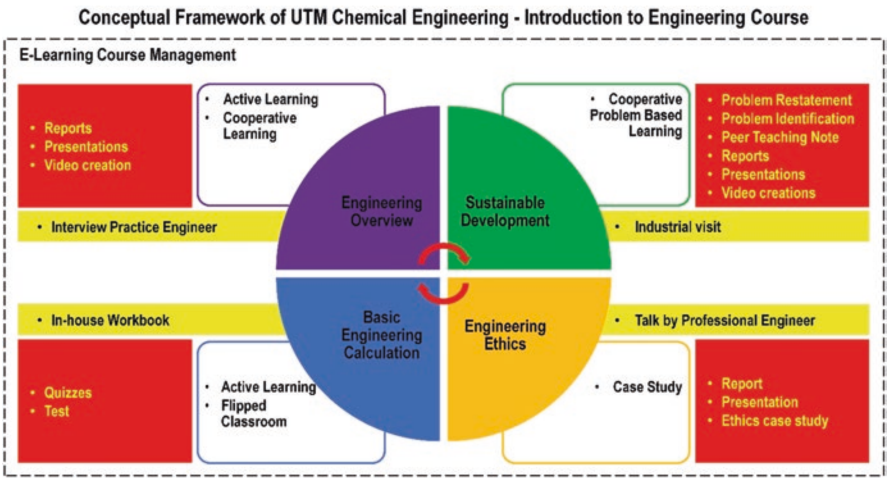

Fig. 3.3 Visual representation of the main topics and the corresponding teaching and learning approaches

Table 3.1 Teaching mode of the topics of the ITE course

No	Topics	Teaching mode	
		Teaching and learning method	Assessment method
1.	Engineering overview (EO)	Active learning Cooperative learning	Reports Presentations Video creation
2.	Sustainable development (SD)	Cooperative problem-based learning e-learning	Problem restatement Problem identification Peer teaching note Reports Presentations Video creation
3.	Basic engineering calculations (BEC)	Lectures/active learning Flipped classroom	Quizzes Test
4.	Engineering ethics (EE)	Case study	Report Presentation Ethics case study

on SD in Malaysia and throughout the world and how to perform benchmarking, as well as designing and planning data collection, and analyzing data collected to identify the source of the problem that they want to provide a solution for – these are the learning issues of the problem that will map the content in the course syllabus. The learning outcome for this segment of the course is that students are able to analyze sustainability-related problem and recommend engineering-based solutions to overcome the problem based on the three pillars of sustainable development using cooperative problem-based learning (CPBL). Preparations of SD problem are made at least 2 months before the semester begins. All ITE lecturers will meet up several times to craft a suitable SD problem based on the chosen theme for the semester and plan for the 14 weeks in the semester according to the CPBL cycle. It is imperative to have a well-designed problem that students can appreciate and become engaged in. Getting the involvement of suitable organizations or industries is a very good way of getting students motivated to seriously learn and solve the problem at a deep level.

The basic engineering calculation preparation follows the first part of the content of a fundamental chemical engineering textbook. Students learn through the flipped classroom approach, where videos on the topics such as unit conversion, dimensions, and fundamental process variables such as flowrates, pressure, and temperature will be uploaded to the course e-learning site. Universiti Teknologi Malaysia (UTM) uses Moodle, a learning management system, for all courses. Students are required to view and comprehend a video before coming to class so that they can straightaway discuss selected questions given earlier during the class. Sets of easy, moderate, and difficult questions will be prepared by the ITE lecturers for the in-class exercise. Online quizzes are also uploaded to help students learn and get feedback on their understanding of the principles when they come to class.

The Engineering ethics is about the professional ethics of engineers as defined by the Engineers' Code of Ethics published by the Board of Engineers Malaysia, required for engineers in Malaysia. Typically, students will read the code of ethics and apply them to the given case study before reporting and discuss the cases in their teams and with the whole class.

Lesson Study for Introduction to Engineering (ITE) Course

The Lesson Study portrayed in this study has been conducted with four sections of the Introduction to Engineering course from a university in Malaysia. Each section was facilitated by two lecturers. This Lesson Study team consists of eight lecturers from the chemical engineering discipline. Their backgrounds are as tabulated in Table 3.2.

L1 is a professor in engineering education who has been strongly advocating student-centered learning at the university, country, and around the world. She has been training all the other lecturers in this team to use SCL approaches to teaching and learning in their classes. The lecturers were first trained in active learning and then cooperative learning, before learning about CPBL. L1 designed and started the ITE course in 2005, which had since evolved after being continuously improved. Some of the lecturers teaching ITE, such as L3, L4, L5, and L8, had co-taught with L1 in one of the ITE sections for at least two semesters, before conducting their own ITE section using CPBL. L6 is co-teaching with L1, L2 is co-teaching with L4, L3 is co-teaching with L5, and L7 is co-teaching with L8. Since L1 has been mentoring the lecturers, Lesson Study is the best way to provide more structured supervision

Table 3.2 Details of the lecturers involved in the Lesson Study

Lecturer	Gender	Position	Teaching experience	Industrial experience	Teaching preference
L1	Female	Professor	25 years	Nil	Training and advocating to student-centered learning
L2	Female	Assoc. prof.	15 years	Nil	Practicing student-centered learning for a few years
L3	Male	Assoc. prof.	15 years	2 years	Practicing student-centered learning for many years
L4	Female	Senior lecturer	12 years	Nil	Practicing student-centered learning for a few years
L5	Male	Senior lecturer	25 years	Nil	Practicing student-centered learning for a few years
L6	Male	Senior lecturer	2 years	Nil	New to practicing student-centered learning
L7	Female	Senior lecturer	4 years	Nil	New to practicing student-centered learning
L8	Male	Senior lecturer	6 years	10 years	Practicing student-centered learning for a few years

among them because of the busy schedules of all the lecturers, especially with their workloads in research and administrative work at a research university.

The team sets its own schedules, decides how often and how long to meet, and distributes the work 3–4 weeks before the start of the first semester of every academic year, when the course is offered. In this study, to understand how Lesson Study was implemented, document analysis was used. The documents collected are the reflections written by the lecturers involved in the Lesson Study at the end of the semester and the course file that contains the lesson plan, notes, and assessment materials.

Formulating Learning Goals

The team begins by selecting goals for student learning. The lesson addresses the following learning goals:

(a) Understand engineering concepts and the roles of an engineer in various aspects.
(b) Perform unit conversions for basic dimensions and calculations for the commonly used process variables in chemical industries.
(c) Develop intellectual abilities on sustainable development and professional skills through CPBL.

Specific learning goals for the ITE course are tabulated in Table 3.3.

Crafting Real-World Sustainable Development Problem

The team makes the choice of the problem theme before the beginning of the semester. The theme should be innovative and aligned with actual societal needs, which requires the use of engineering components, and also challenging to first-year engineering students. Some themes proposed for previous problems were:

(a) 2012 – "Low Carbon Society"
(b) 2013 – "Food Waste Recycled Concepts"

Table 3.3 Learning goals for Introduction to Engineering course

Topic	Learning goals
Engineering overview (EO)	Understand engineering and the roles and responsibilities of an engineer in various aspects
Sustainability development (SD)	Analyze sustainability-related problems and recommend engineering solutions to overcome the problems based on sustainability development using cooperative problem-based learning
Basic engineering calculation (BEC)	Perform unit conversions for basic dimensions and calculations for the commonly used process variables in chemical industries
Engineering ethics (EE)	Understand engineering ethics as defined by the Board of Engineers Malaysia and the institution of engineers Malaysia

(c) 2014 – “Water Sustainability Campaign”
(d) 2015 – “Energy Sustainability Awareness Campaign”
(e) 2016 – “Zero Waste Competition”
(f) 2017 – “Sustainable Trends and Fashion Campaign”.

In the problem for each year, the stakeholder’s involvement was integrated in the problem wherever possible. Students will listen, visit, or interact directly with relevant authority under the ITE and/or seminar courses, which will enable the students to have better comprehension on the actual problematic situation faced by the community, country, and the world. For example, for the low-carbon society (LCS) problem, the Iskandar Region Development Authority (IRDA) located at the Southern Peninsula of Malaysia, a Federal Government statutory body, was tasked with the objective of regulating and driving toward realizing the vision of developing Iskandar Malaysia into a strong and sustainable metropolis of international standing. Some of the ways IRDA became involved were:

- Provide input during problem crafting and vetting the written problem for improvement to ensure authenticity.
- IRDA was the main setting for the problem, as UTM is also located within the Iskandar Region.
- One of the vice presidents of IRDA, Mr. Isma, was named in the problem to provide authenticity.
- Mr. Isma came as an invited speaker during the seminar on LCS and information needed for the problem.
- Location for site visits to view low-carbon township model and houses.
- Sponsorship of prizes for the top three teams of the LCS competition at the end of the problem.

Another example is the “Zero Waste Competition,” which was the sustainable development theme in 2016. SWM Environment Sdn Bhd (SWM) was the company ITE course engaged to assist in showing and guiding students when it comes to solid waste management issues, awareness, and how to solve them. SWM Environment Sdn Bhd (SWM) is an integrated waste management and public cleansing service provider in the southern region of Peninsular Malaysia established in line with the national privatization of solid waste management. Industrial visits to a landfill managed by SWM were also made. Students were exposed with current waste management scenarios, became aware, and were driven to produce innovative solution in line with the theme of zero waste. Likewise, lecturers also benefited from the networking and cooperation with the industry.

Industrial visits were helpful in allowing students to actually see and experience the context of the problem. In 2014, the theme was “Water Sustainability,” and students visited SAJ Holdings, which is an integrated water supply company, involved in the process of water treatment and distribution of treated water to consumers. It can be seen from their faces that the students were very excited, thrilled, and motivated seeing the open water treatment facilities and the control room. For the first time, students felt the vibration and intense noise produced by many huge centrifugal pumps at the facility. They learned significantly from just being there and the briefings presented to them. Such exposure induces positive impact toward the students. Students began appreciating engineering more than before, and vibes of positive attitude can be observed among them.

The examples above show the effort of lecturers to integrate real-world problems into the context of sustainable development within the ITE course by involving relevant authorities and companies, which was very much appreciated by the students.

Planning of Lecturer's Guide

Designing and planning is a crucial step to ensure a conducive and supportive learning environment that is constructively aligned to reach the outcomes. Every time the course is offered in the first semester of the academic year, a new semester starts with this step, considering lessons learned during the past semester. The course is integrated with the 1-credit industry and professional (seminar) course. The topics of talks and visits during the seminar times are coordinated with the topics in ITE as a form of support and motivation for students. In the seminar, during the engineering overview topic in the ITE course, practicing engineers from different industries and organizations were invited to share their expertise and real experience in the workplace.

Since its inception, the teaching and learning approach for ITE had evolved and was improved to its current implementation. In 2005, cooperative learning was utilized in the course and was combined with problem-based learning in 2006 for supporting students to learn sustainable development. The principles of CL were infused into the PBL process, and a formalized framework for the CPBL model was developed in 2008 and published (Mohd-Yusof et al. 2011). CPBL, as shown in Fig. 3.1, is applied in the ITE course, where part of the class was designed to general topics about engineering and the other part was dedicated to the project. The implementation of the CPBL in the class is to enhance student learning, and it has been proven as an effective way to prepare students for professional careers. CPBL does not only scaffold students to reach deep learning but also to develop professional skills such as team-based problem-solving (Helmi et al. 2016).

Table 3.4 is a sample of the detailed lesson plan of the integrated ITE and seminar courses. Planning must be done and discussed among all the lecturers teaching the ITE and seminar courses so that everyone will have a clear idea while conducting the courses. Referring to Table 3.4, the different teaching and learning approaches for the ITE course are taken into account in the plan. For example, each phase of the CPBL cycle is included, so that all the three CPBL phases in each of the three stages of the sustainable development-based problem can be properly implemented during the semester. As seen in Table 3.4, Stage 1 of the problem (CPBL 1) is given a duration of 2 weeks, starting with Phase 1 of CPBL where the problem is posted and the problem restatement and problem identification are made (PR and PI). All the other topics and the corresponding teaching and learning approaches used are also clearly designated to the duration that is needed.

Table 3.4 The outline of weekly implementation of the course and each phase of the CPBL cycles

Week	Topic	What lecturers should do: ITE	What lecturers should do: seminar
1	Course outline Overview Semester system	Introduction to the course. Introduction to cooperative learning and team formation. Team formation and ice-breaking. Presentation team name, motto, logo.	Seminar: The semester system. Program curriculum, syllabus overview. Outcome-based education (OBE). Workshop. Application of search engine on the internet for research purposes.
2	Engineering overview	Assignment on *Engineering Overview* – Students need to find their own topics or define the problems that need to be solved and related articles Discuss articles found on their topics in each team. Guide students to find ways to link with engineers for their teams. Craft questions to ask engineers.	Workshops: Information searching through UTM website. Learning and reflection journal: What, why, and how?
3	Engineering overview. Chemical and, Engineering and 5 M concepts,	Presentation and closure engineering overview. What is chemical engineering and 5 M concept.	Seminars: Definition and basic roles of an engineer – Practicing engineers as invited speaker. Being a professional engineer – Roles of BEM and IEM.
4	CPBL 1	Post stage 1 problem Students do individual PI and PR. Team consensus in PR and PI. Class discussion in PR and PI. Self-directed learning on learning issues. Class peer teaching.	Workshop: Introduction to Microsoft excel Introduction to Microsoft PowerPoint and basic presentation skills
5	CPBL 1	Stage 1 presentation and closure	Seminar: Effective public speaking.
6	CPBL 2	Post stage 2 problem Students do individual PI and PR. Team consensus in PR and PI. Class discussion in PR and PI. Self-directed learning on learning issues. Class peer teaching.	Seminar: Solid waste issue and experience sharing – Experts as speakers.
7	*Midterm break*		
8	Chapters 2 and 3	Flipped classroom	

(continued)

Table 3.4 (continued)

Week	Topic	What lecturers should do: ITE	What lecturers should do: seminar
9	CPBL 2	Progress check for self and student audit. Team synthesis for formulation solutions. Team consensus on final solution generation.	Seminars: Success and failure factors in university. Purpose of university education. Pitfalls to avoid.
10	CPBL 2	Presentation stage 2 and closure	
11	CPBL 3	Post stage 3 problem Team consensus in PR and PI. Class discussion in PR and PI. Class peer teaching.	Seminar: Problem-solving using the theory of inventive problem-solving – Level 1 Theory of Inventive Problem Solving (TRIZ) trainer as invited speaker.
12	CPBL 3	Team synthesis and application for formulation solutions. Team consensus on final solution generation.	
13	Ethics	ITE ethics. Ethics case study. Test Chaps. 2 and 3.	Seminar: Engineering code of ethics – Professional engineer as invited speaker.
14	CPBL 3 and closure	Stage 3 presentation and closure Video submission.	

Teaching and Observing

Two lecturers for each section teach and facilitate the lesson and attend the class to collect data. One lecturer teaches the lesson as designed, while the other lecturer observes the class, taking notes regarding the reaction and engagement of the students. The lecturers focus on how students respond to the lesson. They gather rich evidence related to the learning goal during the lesson, capturing the complexity of actual teaching and learning. The tools used in data collection are students' assessment, analysis of students' behavior during classes, and questionnaires answered by the students. The lecturers took notes, focus on student activity, and monitor student engagement, performance, thinking, and behavior. They observe the entire class and also focus on specific students during the lesson. Some lessons were videotaped, for future reference and review.

Analyzing the Evidence and Improving the Lessons

Soon after the lesson was taught, the team holds a debriefing meeting to examine evidence related to the learning goals and to reflect on the experience. They analyzed how students learn, focus on student thinking during the lesson, what kinds of difficulties student have, how they answer questions, how their thinking changes during the lesson, and so forth. They share their observations and examine additional evidence from the lesson, such as students' written work, searching for patterns that may reveal important insights into teaching practice and student learning. From the analysis, an action plan is elaborated to be implemented in the following semester, and it aimed to answer questions as follows: What needs to change? In what parts of the project? What type of change is required? Whose support is required? Based on experience and evidence, the lesson is revised and taught again, and the process is repeated.

Findings and Discussion

Improve Planning

Often, lecturers do not have the time or skill and even the guidance to plan. Lesson Study provides an opportunity for them to sit down and plan. In this team of lecturers, L1 serves as a guide to other young lecturers who are new or have just started practicing student-centered learning (SCL). In the reflections, L4 said that it is only through this Lesson Study that she knew about how to do a lesson plan and prepare a guide. They are more prepared to teaching, and this is similar to the findings of Ong et al. (2010). Other lecturers also said that what they have learned in this Lesson Study is on planning:

> After 4 years of teaching this course, I have learnt the importance of good teaching plan and preparation to ensure a smooth delivery during teaching and learning. – L7

> I have learnt how to do class activities planning. The planning should also include another course to support Introduction to Engineering (ITE) course, which is Industrial Seminar and Profession (Seminar). Since I am also the coordinator for the Seminar course, the planning is basically an excellent experience for me to synchronize activities in ITE and Seminar. – L3

As pointed out by Cheah and Lim (2010) and Tan and Nashon (2017), Lesson Study is an effective way to introduce a new teaching and learning approach among educators. In this case, student-centered learning approach can be learned and practiced by the younger lecturers who are new or somewhat new to the approach and continuously guided by the senior lecturer, L1.

Cooperation Among Lecturers

Most of the lecturers also enjoyed the experience of cooperating with other lecturers in conducting classes which is not a widespread practice at the university. The lecturers admitted that they learned how to work together with other lecturers through the exercise of Lesson Study, for example:

> I have also learnt on how to cooperate with each other (lecturers) especially in deciding some topics, learning issues, creating problems, and assessments. This is impossible when we are doing it individually. – L3

> I worked collaboratively with other lecturers when designing lesson plan and designing activities. – L4

The cooperation among the lecturers is very important because it helps to share the workload, complete work faster, learn from each other, get more diverse ideas from different perspectives, and thus improve the teaching plans and ideas and even make assessment more objective. They commented in their reflections:

> Providing fast feedbacks to students is also crucial to ensure the efficiency of learning process. In addition, having team teaching which consist of both junior and senior lecturers also enables better brainstorming of ideas and smooth execution of works. – L7

> Everything went very well as we planned when we taught our lesson. We did plan the lesson perfectly in terms of timing. My team teaching was L2. She was fantastic, and I have learned so much from her. – L4

> So far, I have partnered 3 lecturers and I learned a lot from them, and I hope they also learned something from me. I am happy to be with my existing partner as we are able to successfully run the class together without problem. I have experienced being with 1 lecturer whom I cannot work with her. It is not my intention to highlight this, but I must mention that to run a class with 2 lecturers, both of them need to have the understanding. Both must have good commitment and know his/her responsibility towards the class. – L8

> In addition, the assessment of all class activities and deliverables are also improved in terms of coordination and standardization of the assessment scheme. This is because, all deliverables will be assessed either by one dedicated lecturer or group of lecturers. This will avoid the bias or being unfair in doing the assessments. – L3

This finding is in agreement with Demir et al. (2013) where collaboration among lecturers can be fostered through Lesson Study.

Time Management

In terms of time management, there are both positive and negative sides reflected by the lecturers. Some said that it is because of doing Lesson Study, with many meetings, planning, and coordination that they learned to manage their time properly and prepared earlier. However, there are also lecturers who complained about too much time spent for meetings and discussions. For example:

> There are so many things that have been improved, for example, the time management for the class activities is drastically improved. – L3

> The workload of this course is massive as it implements CA and CL, also the requirement of new sustainability problems and ideas for each semester. However, everything works well as every lecturer play their role and share the burden together. Usually we will have frequent face-to-face meetings before the semester starts. Informal discussion through email and WhatsApp is also conducted whenever needed. – L8

> It is good to have meetings to discuss about the class, but too many meetings sometimes can be quite damaging. Some lecturers are complaining about having too many meetings. Despite knowing the importance of having the meetings, we still complain. Hence, maybe something also need to be done about the frequency of the meetings. Some of the lecturers have no issues on the meeting frequency, but some feel it is quite a nuisance. Maybe, it is because the meeting venue is far away from the faculty office that these lecturers need to travel? Maybe…? – L8

It may be down to the individual lecturers in looking at time management.

Lecturers' Confidence

Through Lesson Study, it helps the younger lecturers to be more confident to practice teaching approach and methods that they were not comfortable but effective for learning such as active learning, cooperative learning, flipped classroom, and problem-based learning. This is because they received guidance from the senior lecturers (L1) who they see as mentors in their teaching.

> After getting the confidence from this course, I have slowly implemented active learning and cooperative learning in other courses as well. – L7

> Flipped classroom worked very well. My students enjoy class discussions, because we work on what they need to cover. In turn, I benefit from better engagement and honest effort when it comes time for them to demonstrate what they've learned. My class is noisy, engaging, flexible and accommodating. We pace discussions based on students' needs to work through practice problems multiple times. My classes are more efficient, students learn faster, and all of us are satisfied with the flipped classroom strategy. – L4

> Most importantly, I learned the concept of AL, CL and CPBL which is very good. Before this I do not know about this. Now I am taking the initiative to develop the same approach for my other classes that I teach. – L8

Lesson Study has become a platform to train new lecturers to practice new teaching and learning approach and methods through better mentoring, guidance, and constant feedback via teaching observation, discussion, meetings, and working in pairs.

Innovation Mind-Set

In terms of the innovation mind-set, through Lesson Study, it helps in developing the innovation mind-set among the younger lecturers especially when they facilitated students in solving innovative sustainable development problems. This is because they always received guidance from a Senior Lecturer (L1) who is also a Level 1 TRIZ-certified trainer.

> After pairing with L1 for several times, I have slowly improved my innovation perspective and started to do some simple innovation such as applying copyright for my teaching and learning materials. – L3

> My overview of innovation has been expanded since joining this course. Pairing with L1 has helped me in guiding students to extend what they have solved in this class to the higher level such as participating in the innovation competition and exhibition. – L8

> I am the younger one in this team, so I am always the one who do the copyright documentation and application for the problem. However, it is basically trained me become a good inventor in the future. – L6

Major Challenges in Implementing the Course Model

The preparation of effective Lesson Study is not easy and a real challenge for many lecturers including those involved with this ITE course. Many issues have been raised and highlighted since the implementation of integrated Lesson Study for all ITE sections. Among the challenges are the following:

1. Since the ITE course is conducted based on various active learning approaches, the preparation of Lesson Study is not easy as it involves collaborative planning consisting of a team of lecturers (eight lecturers for four sections). Thus, it is very important to have regular meetings during the preparation of Lesson Study and during the course implementation. Getting the meeting time that is available for all lecturers is a challenge as all the lecturers are quite occupied with their other commitments. Therefore, in certain cases, meetings must be conducted even without complete attendance of the lecturers involved. However, post-meeting discussion is continued or conducted through online medium such as WhatsApp or email.
2. Things could go differently from what have been planned, for example, the cancellation of classes during a worsening haze situation resulted in sudden changes in the prepared lesson plan. Thus, to cope with the situation, the prepared planning should have enough room for flexibility. The lesson should not be planned with an exact structure to be followed. There must be built-in flexibility so that any issues that may arise can be dealt with.
3. Last but not least, the effectiveness of the lesson plan requires full commitment from all lecturers involved. All lecturers must come to a mutual agreement and share the responsibility especially for collaborative activities. Failure to do so will decrease motivation and create an unhealthy relationship among all lecturers.

Despite the challenges in implementation of the multiple-section course using various innovative approaches as well as integrating industries and organizations, the use of Lesson Study facilitated rapid enhancements in guiding all the lecturers to reflect toward improving how the course is conducted. The approach in utilizing Lesson Study can also be scaled up for groups of lecturers teaching the same cohort of students and even for the whole program. Peer observations can provide different perspectives in the learning environment in different courses and allow lecturers to receive feedback from a colleague who would understand the content and students.

This will not only help the lecturer being observed but also the lecturer who conducted the observation.

Conclusion

From the reflection, it is found that the lecturers have learned a lot from each other, especially from the lead lecturer, particularly in meaningfully integrating industry partnerships in the class curriculum with effective implementation. They are also more prepared and confident in the classes and know what and how to improve their teaching as well as learning to manage their time better. However, to conduct Lesson Study, commitment and discipline are highly important.

Lesson Study supports instructors to use Lesson Study practices to improve teaching and learning in higher education. This work illustrates a detailed, usable lesson plan and an in-depth study of the lesson that investigates teaching and learning interactions, explaining how chemical engineering lecturers responded to planning, implementation, and instruction and how instruction might be further modified based on the evidence collected. Lesson Study is an effective method to improve the Scholarship of Teaching and Learning at the higher learning institutes. It is particularly important when implementing impactful approaches, such as when integrating industry involvement that requires efforts from more than a single faculty member. This paper provides a framework on how to practice Lesson Study to teach engineering. This can become a good practice to mentor new and inexperienced lecturers.

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Chapter 4
Implementing Real-Life Engineering Problems as a Means of Learning in Part-Time Engineering Master's Programmes

Bente Nørgaard

Introduction

The development of employees' skills and competences has become a key driver of economic growth in the world. This is also a factor in the field of engineering, where it is widely recognised that it is mainly through enhancing engineering skills and competences that future competitive advantage will emerge. Consequently, both the individual engineer and employers of engineers need to continuously upskill in areas where they have, or can build, distinctive competences that will enable them to compete effectively and, for example, develop new products. However, enhancing the qualifications of professional engineers is a challenging area. Firstly, it can be difficult to identify precise needs for competences and, secondly, it can be difficult to find courses that match the identified needs. This can turn out to be a challenging puzzle. Even though the diversity in continuing education is large, ranging from short crash courses, with a duration of 2 to 4 days, to accredited programmes of full-time study, the content of these courses, or what is immediately applicable in the professional engineer's daily work, might only be a small part of the course content. Hence, the outcome of continuing education courses seldom entirely fulfils the expectations of the professional engineer and the employer.

In Europe and around the world, several part-time master's programmes can be found. However, they vary greatly in pedagogical approach, from traditional classroom teaching to student-centred approaches and from solely online programmes to those taught face to face. But the student-centred approaches, problem-based learning (PBL), and the 'conceive-design-implement-operate' (CDIO) approaches (Metropolia.fi and AAU.dk) are offered less, and it seems that part-time master's programmes within the humanities and the social sciences (MBA studies) predominate compared to part-time master's programmes in engineering.

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For more than two decades, Aalborg University has enrolled professional engineers in continuing engineering programmes as part-time master's programmes, which to a large extent implement real-life engineering problems as a means of learning. These part-time engineering master's programmes are designed for employed learners who work full time in the industry and who want to keep their jobs while they study for a master's degree. Consequently, the courses and seminars are mainly given in the evening and during weekends. These part-time programmes should not be mistaken for the traditional master of science programmes (120 credits in the European Credit Transfer System, or ECTS), which, according to the Bologna Process in higher education in Europe, is 2 years of study following a bachelor's degree. The part-time master's programmes are specially prepared to meet the needs of employed learners who lack knowledge, skills, and competence within a precisely identified subject (profession). Derived from PBL pedagogy, the curricula are carefully designed such that they encourage authentic problems from the learner's professional life as a means of learning. Although PBL projects require exemplarity (Barge 2010), part-time master's programmes offer many opportunities for the individualisation of education through project work, which ultimately has educational relevance to both the student and the employer.

Part-time master's programmes derived from a PBL approach, however, seem to meet some of the challenges regarding not meeting the needs of the adult learner and the employer. This concept of 'posing problems' as a means of learning began in the 1960s when Paulo Freire described 'the banking concept of education', which is still prevalent as 'education becomes an act of depositing, in which the students [learners] are the depositories and the teacher is the depositor' (Freire 2009, p. 72). This educational approach, with the teacher as narrator of a subject and learners listening to memorise the narrated content, is something that we are all, to some extent, familiar with. But, as Freire (2009) argues, this teacher-centred approach must be rejected: 'they must abandon the educational goal of the deposit-making and replace it with the posing of the problems of human beings in their relations with the world' (Freire 2009, p. 79). Abandoning the banking concept and implementing the posing of problems is one of the backbones of PBL and, hence, the problem orientation and problem definitions. Another pioneer in the field of 'posing of problems' was Howard Barrow, who in the late 1960s was involved in the early stages of the development of PBL at McMaster University in Canada. Barrow defined the concept in terms of specific characteristics as being student-centred, taking place in small groups with the teacher acting as a facilitator, and being organised around problems (Du et al. 2003, p. 657). In Denmark, the PBL model was developed based on ideas from, among others, Illeris, 'who formulated the principles of PBL as problem-oriented, project work, interdisciplinary, participant directed learning and the exemplary principle and team work' (Kolmos et al. 2004, p. 10). Then for more than 40 years, PBL not only has survived but has grown and evolved due to research, development, and implementation in several higher education institutions across the world, resulting in different PBL models and practices (Guerra et al. 2017). PBL is also a powerful tool to achieve sustainable development. For example, in African countries with PBL, local developmental problems have been brought into the educational sphere, thus ensuring that students contribute to local development. Furthermore, PBL increases the creativity and innovativeness of students, thus enhancing the role of universities in national systems of innovation (Dahms and Stentoft 2008). And in a continuing education contest, Biggs and Tang (2003) express that PBL reflects the way people learn in real life; they simply get on with solving the problems life puts before them with whatever resources are at hand.

The Aalborg PBL model is a problem-based and project-organised model, which has been gradually developed at a profession-based level. However, it is important to recognise that the model and its identified principles are by no means static or contextually isolated but should always be interpreted in the light of the broader context in which the model is to be implemented and applied. The PBL principles that are acknowledged by Aalborg University are as follows:

- Problem orientation: Problems/'wonderings' appropriate to the study programme serve as the basis for the learning process.
- Project organisation: The project stands as both the means through which the students address the problem and the primary means by which students achieve the articulated educational objectives. The project is a multifaceted and often extended sequence of tasks culminating in a final work product.
- Integration of theory and practice: The curriculum, instructional faculty members and project supervisors facilitate the process of connecting the specifics of project work to broader theoretical knowledge for the students. The students are able to see how theories and empirical/practical knowledge interrelate.
- Participant direction: Students define the problem and make key decisions relevant to the successful completion of their project work.
- Team-based approach: A majority of the students' problem/project work is conducted in groups of three or more students.
- Collaboration and feedback: The students use peer and supervisor critique to improve their work. The skills of collaboration, feedback, and reflection are an important outcome of the PBL model (Barge 2010).

All students and staff put into practice these basic principles of PBL, which is a general characteristic of all studies at Aalborg University. The Aalborg PBL approach can be illustrated as a process of problem analysis, problem solving, and, finally, reporting of solutions and the work process. This process is supported by lecture, peer learning, group studies, literature, tutorials, field work, and experiments as illustrated in Fig. 4.1.

Aalborg University is an interdisciplinary university that includes faculties of technical and natural sciences, social sciences, humanities, and medicine, each of which offers a number of master's programmes. Not all programmes are taught in English, but one – the part-time master's programme in building physics – has been selected for this study as the context for demonstrating the problem-orientation process among adult learners. The master's programme in building physics is a research-based education programme that enrols researchers and leading experts in the field, and which applies current scientific theories and methods to practical

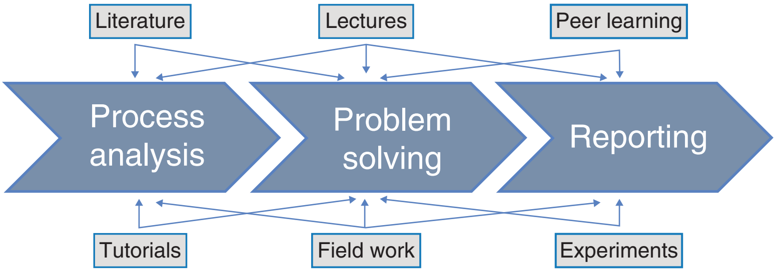

Fig. 4.1 Aalborg PBL process

building-related issues. This programme is an accredited, qualifying continuing education programme, aimed at all professional groups with a long or intermediate higher education in the field of construction, such as civil, diploma and academic engineers; building engineers; and architects.

In addition to a relevant higher education, it is required that the learner should have at least 2 years of practical experience at a high level of construction. This practical experience enables the learners to bring real-life problems with them into the master's programme, which will be exemplified later in this chapter.

Problem-Based Learning in Master's Programmes

Aalborg University's pedagogical approach is solely based on the educational concept of PBL, which means that all the students and staff enact the basic principles of PBL, including in the part-time engineering master's programmes. They are designed according to the Aalborg PBL principles, that is, they are problem-based and project-organised. The learners collaborate in teams, applying theory and method to solve real-life engineering problems. These principles influence how the students identify real-life problems and also how they document this through their project work.

The use of problem definitions as a means for learning, the problem orientation, is one of the pillars in a PBL project, which differs from other types of project work as identified by Kolmos (1996), Graaf et al. (2003), Kolmos et al. (2008), and Holgaard et al. (2015):

- Task projects: These are 'teacher selected', and the problem, method (an academic discipline), and possibly subject are chosen beforehand.
- Discipline projects: These are 'teacher directed', and the method, discipline, and subjects are given beforehand.
- Problem-based project: This is a problem-oriented project in which the problem will determinate the choice of disciplines and methods (Kolmos et al. 2008, p. 30) and the choice of subject (Kolmos 1996, p. 142.). The students themselves choose the problem.

In relation to the master's programmes, problem orientation becomes even more applicable since the learners are professionals with work experience from which problems can be identified. From a learning perspective, the context of the problem has to be as authentic as possible. So, if the context is the learner's workplace, then all things being equal, the criteria for relevance must be met. Another observation that speaks for problem orientation in continuing engineering education is the fact that '53–88% of the participants in continuing educations are adults who are work-related motivated' (Lorensen 2010). The learners are work-related motivated and this may support problem-orientation; hence, the learner has experience work-related qualifications and benefits.

There have been many academic discussions about what a 'problem' is. Overall, Kolmos (2003) argues that definitions of problems are diverse in different professional areas. Qvist (2004) has, from a literature review of diverse problem formulations, located a variety of definitions. Basically, there is consensus that a problem can be initiated by a wondering, a problematic situation (Qvist 2004; Guerra and Bøgelund 2015), or an unexplored potential (Guerra and Bøgelund 2014 with reference to Barrows and Tamblyn 1980; Qvist 2004).

- A wondering: This indicates an observed phenomenon creating (qualified) curiosity (Qvist 2004), which can include situations, events, persons, or a thing (Guerra and Bøgelund 2014), something that happened or happens, something heard and seen (Qvist 2004), an uncovered need or wish (Guerra and Bøgelund 2014; Qvist 2004).
- A problematic situation: This can, according to Qvist (2004), be 'something you find a scandal', 'a lack of knowledge', or 'a lack of function', and it can be caused by contrasts (such as between a wish and reality), conflicts, and contradictions (Guerra and Bøgelund 2014; Qvist 2004). In the definition of a problem, Guerra and Bøgelund (2014) explain a problematic situation as also including the students' sorrow and/or indignation, frustration, or stress, which makes them act to change this problematic situation.
- An unexplored potential: This idea is also a possible starting point for the problem formulation, such as the potential of a mobile phone not only as a device for communication but also for taking photographs and video, writing agendas and e-mails, running GPS applications, and so forth.

Furthermore, consistent with the Aalborg PBL model, problem definitions can be categorised as theoretical, practical, social, technical, symbolic-cultural, and/or scientific (Barge 2010, p. 7). Depending on the type of problem and its starting point (a wondering, a problematic situation, or an unexplored potential), there is also a distinction between 'retrospective' or 'prospective' problem formulations (Holgaard et al. 2013, p. 37), which can be characterised as follows:

- Retrospective problems seek justifications and explanations for something that has already happened.
- Prospective problems are designed to solve practical problems and to produce concrete solutions.

In summary, problem orientation, or problem definitions, as one of the basic principles of PBL, cannot be described and categorised as only one type of problem. Problem orientation is a concept that relates to various types of problem definitions with different points of departure, implementing distinctive theory and methods that are the means for solving the problem and which are documented by the learners in their project work. Besides the three defined starting points of the problem-oriented project work, there is also the influence from the academic discipline, the supervisors, and not least the topic of the semester, which is described in a 'semester catalogue' that essentially sets the frame for the characteristics of problems defined for each semester.

A discussion on problem orientation and how it can be identified from the case will follow the description of the master's programme in building physics.

The Master's Programme in Building Physics

As a case, the master's programme in building physics has been chosen to illustrate how learners are able to identify problems as a means of learning. The programme has a duration of three trimesters and in total it is a 60 ECTS-credit programme, in which one ECTS equals 30 working hours. Each trimester consists of both courses and a PBL project; however, the capstone PBL project is 15 ECTS. Figure 4.2 shows the structure of the programme and the trimesters.

The capstone project of the semester has a background in two urgent challenges of social significance:

- More than a third of the total Danish energy consumption goes to the heating of buildings. To realise the goals set by the EU and the Danish government to reduce CO_2 emissions, it is imperative to significantly reduce the energy consumption of buildings.
- More than half of all building damage is caused by dampness/condensation, such as in relation to energy efficiency and post-insulation. Much of the damage arises due to a lack of knowledge or errors in design or execution. This results in an increased risk of accumulation condensation, which may cause mould and a poor indoor climate, as well as, in the long-term, degradation of materials and construction.

	1st TRIMESTER THEME: DAMP INSULATION	2nd TRIMESTER THEME: ENERGY CONSUMPTION	3rd TRIMESTER MASTER PROJECT
Courses	10 ECTS	10 ECTS	5 ECTS
Project	10 ECTS	10 ECTS	15 ECTS
Total	20 ECTS	20 ECTS	20 ECTS

Fig. 4.2 Building a physics programme

Large energy savings in the construction industry can be difficult to achieve in building engineering as well as in economic and cultural terms, and the consequences of possible water damage result in additional complexity. In view of these challenges, there is a need for an increase in competency among several professional groups in the building and property sector.

In order to complete the programme, the learners must complete a master's capstone project in building physics which, according to the curriculum, has the following theme and learning outcomes:

The master's dissertation is written within the building area and contains a presentation of previous research in the field and the Master's project in relation to this.

The master's dissertation must demonstrate that you have profound knowledge of one or a few selected subject elements and a broader insight into the field of construction in terms of theories and methods as well as their interrelationships, possibly in connection with a renovation or new building project.

As part of the master's dissertation, the learners will demonstrate the following: independently, systematically, and critically identify, formulate, and analyse how the current issue relevantly relates the problem to the subject, including explaining and justifying the choices made in the delimitation of the problem and putting the current issue into a historical context.

The master's dissertation must show that learners are able to independently take and justify the choice of scientific, theoretical, and/or experimental methods and independently and critically assess the chosen theories and methods as well as the project's analyses, results, and conclusions to convey relevant academic and professional aspects of project work in a clear and systematic way.

The learning outcomes are identified according to the Structure of Observed Learning Outcome (SOLO) taxonomy (Biggs and Collis 1982; Biggs and Tang 2003), which is a model that describes levels of increasing complexity in a learner's understanding of subjects. It aids both trainers and learners in understanding the learning process. The model consists of five levels in the order of understanding. However, in this education, the five SOLO levels are adapted into three levels: 'Knowledge' relates to levels two and three, 'skills' relates to level four, and 'competences' relates to level five. The learning outcomes according to the SOLO taxonomy are categorised as verbs, as illustrated in Fig. 4.3.

The following are learning outcomes according to the curriculum of the building physics programme:

Knowledge – the student must have obtained:

- *In-depth knowledge of one or more selected subject elements.*
- *Wider insight into the field as regards theories and methods, as well as their mutual context, possibly in connection with a renovation or new building project.*
- *Skills – the student must have the following skills:*
- *Independently, systematically, and critically identify, formulate, and analyse the current problem formation.*
- *Relevantly relate the problem formation to the subject, including explaining and justifying the choices made in the delimitation of the problem formation.*

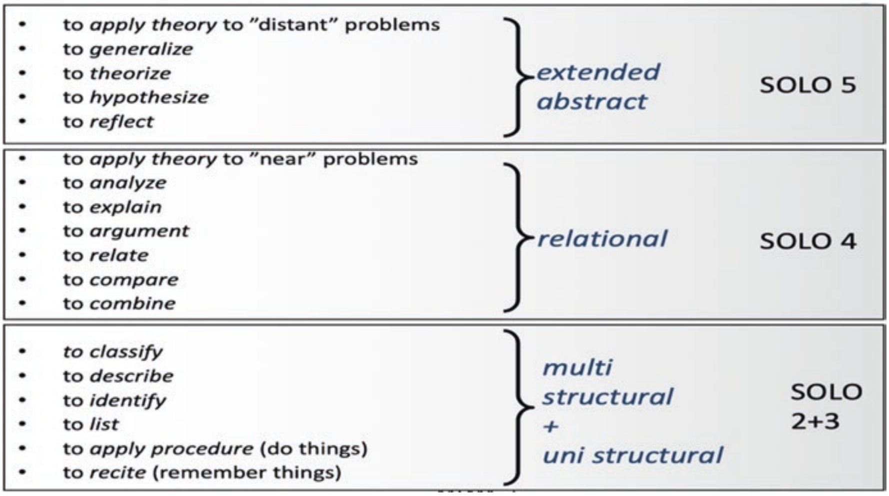

Fig. 4.3 Adapted from Biggs and Collis (1982)

- *Relate the subject of the project to a historical context.*
- *Competences – the student must have obtained the following competencies:*
- *Independently take and justify the choice of scientific, theoretical, and/or experimental methods.*
- *Independently and critically evaluate the chosen theories and methods, as well as the project analyses, results, and conclusions.*
- *Communicate relevant academic and professional aspects of project work in a clear and systematic way.*

These are the goals for the learners, which should be followed throughout their master's capstone project to demonstrate that they have achieved the defined learning outcomes, according to knowledge, skills, and competences, which will be the basis for the assessment.

Examples of Problems Defined in the Frame of the Building Physics Programme

In the light of the two urgent challenges that have been identified (i.e. the need for energy savings and damp-sensitivity in construction), the learners have identified the problem definitions to guide the learning process through their master's capstone project:

Case 1: Indoor condensation insulation of an older brick-built basement – a case study and theoretical analysis of mineral insulation panels:

How do the different types of insulation plates react to each other, and does it matter what type of surface treatment is used? (Møller 2015).

Case 2: Bathrooms instead of back stairs: the conditions for establishing bathrooms in an existing back staircase:

What are the damp conditions in a shared bathroom in a basement, a bedroom with shower cabinet, and existing back stairs? (Mefail 2016).

Case 3: The thermal and atmospheric indoor climate in offices:

What is the relationship between the measured and experienced thermal and atmospheric indoor climate in a number of offices in the city of Rødovre and the city of Copenhagen? (Pedersen 2015).

Case 4: Calculated energy versus measured energy consumption:

How much is the energy requirement that is calculated in connection with the design of the building in relation to the energy used when the building is constructed and in operation? (Andersen and Justinussen 2016).

Case 5: A study of the options for indoor climate and energy renovation in primary schools:

This project examines whether or not there is a correlation between energy consumption (in terms of energy labels of the building) and the poor indoor climate in the public schools in Denmark (Lorentsen 2015).

On the basis of the problem definitions, it is, of course, not possible to tell how well the learners have managed to meet all the learning outcomes set forth in the curriculum. However, it is possible to see whether the problem definitions are aligned with the topic of the semester and what type of problem definitions the learners are able to come up with.

Discussion

These five different examples of master's project problem definitions were randomly selected from the programme. As the examples demonstrate, the learners identified innovative and real-life problems from their respective employment. Even though their backgrounds and jobs are very different, they all managed to draw up problem definitions from their professional life that also match the curriculum of the master's programme in building physics. Even though the five problem definitions were identified within the same programme (curriculum), they are diverse due to the different professional areas that the students worked in (Kolmos 2003). The problem definitions can each be identified as 'a wondering' since the learners explore phenomena which create curiosity that can be disclosed. They can also be identified as retrospective projects because they seek justifications and explanations in regards to the phenomena. The problem formation in case 1 can be categorised as 'a problematic situation' because the project explores a lack of knowledge of different isolation plates and in their use. The problem formation is also designed to solve a practical problem, which is characterised as a prospective project. This is also the case for the problem formation in case 2, which produces a concrete solution to a practical problem. However, the problem definitions in case 2 can be identified as 'an unexplored potential' because the project explores the conditions for establishing bathrooms in a back staircase.

This analysis of the five problem definitions reveals their differences. Even when identified within the same curriculum, the diversity is clear. Nevertheless, they all are 'discipline projects' (Kolmos et al. 2008) because the method, discipline, and subjects are given beforehand and the learners have chosen the subject within a rather narrow area of building physics. Additionally, only one of the selected problem definitions was completed through group work (two learners). The other four were completed by individual learners, which is a high share of individualists compared to Aalborg University's usual students in this master's programme. This might be due to the real-life problem definitions: the learners are work-related motivated and want to explore their 'own' professional practice and context.

The five selected problem definitions reflect the learners' ability and show that they are able to identify real-life problems within the curricular frame of the master's programme in building physics. However, the learners have identified diverse problems due to their different professional contexts and practice.

Moving to a meta perspective, the master's programmes seem to fulfil the European Union's attempt to better link together key concepts such as research, education, and innovation. These concepts are also referred to as the Knowledge Triangle, which are key drivers of a knowledge-based society. Adapting the master's programme to the Knowledge Triangle, the innovation in companies is often a process related to or even identical to the problem-solving process. Thus, when companies enrol their employees in master's programmes and identify company-authentic problems or innovation, the analyses and solutions will be facilitated by university academic staff, but with the focus on the learning of the employee, the professional engineer. Figure 4.4 displays an adapted Knowledge Triangle, where the link between actors is seen.

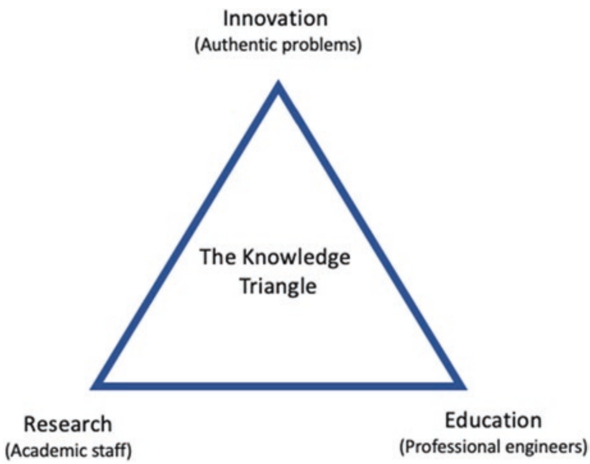

Fig. 4.4 Adapted Knowledge Triangle

In the ideal setting, the company will obtain solutions to its relevant problem; the professional engineer will gain new knowledge and competences, and further become more employable; and the university will gain knowledge on practical problems and meet the goal of knowledge transfer from university to companies.

Conclusion

The part-time master's programme in building physics was presented as a case to demonstrate the types of problem definitions that learners are able to identify from their work life. The intention was also to demonstrate alignment with the requirements of the part-time master's programme; hence, the learners are able to identify real-life problems within the frames of this programme. The problem definitions are all aligned with the two overall identified topics of the semester: the need for energy savings and damp-sensitivity in construction. However, this rather narrowly identified topic of the semester leads to 'discipline projects' through which the problem definitions are solved. When it comes to the type of problem definitions the learners are able to identify, this case shows that the five randomly selected problem definitions are initiated by a wondering, a problematic situation, and an unexplored potential. These three ways of understanding problems are represented in the case and are retrospective and prospective perceptions of the problem definitions. The diversity of the problem definitions reflects the learners' work-related motivation because the problem definitions are all initiated by their professional practice and context. This also makes the part-time master's degree programme highly relevant in relation to the orchestration of the Knowledge Triangle.

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Chapter 5
New Information Technology Pattern-Based Secure BIM Learning through Education-Integrated Engineering System

Assam Hammi and Abdelaziz Bouras

Introduction/Context

Building information modelling (BIM) comes with its intelligent process based on 3D model and information to provide AEC professionals the tools and ways to design, to construct, and to manage building/infrastructure efficiently. Due to its enormous importance, the UK government is mandating it on all public projects from 2016 onward to benefit from all its advantages. In fact they are in Level 2 of BIM maturity and they will move to Level 3 from now to 2015, which is more in-depth in terms of processes and workflows (Cable et al. 2013). BIM includes a wide variety of concepts, tools, and workflows which need to be learned and applied by industry stakeholders (Succar et al. 2012). BIM Education covers the procedures for obtaining the necessary knowledge and the required skills to establish BIM deliverables and meet clients' requirements. Besides BIM Education is the process of learning the sum of theoretical and practical knowledge linking to BIM technologies, workflows, and protocols (Succar et al. 2012). At this age of information technology (IT) revolution, BIM is a new field of technology which is currently posing some challenges to educators in terms of its teaching and training, which arise from the lack of resources for knowledge, skills, finance, and time, coupled with its influences on project delivery processes (Yusuf et al. 2017). To ensure the success of an integrated curricula, we have to be motivated to use BIM; this can be accomplished for industry by the governments and major clients' pressure applied, and the opportunity to improve profits and competitiveness (Riel 1998).

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The above section underlines the relation between BIM and IT, while Section "State of the Art" of this chapter touches some of the main works related to BIM education curricula within the higher education institutions at an international level; following this, Section "BIM and Security Issues" focuses on the current issues related to the safety needs in the BIM process and highlights some of the possible solutions to address those needs. Section "Blockchain based Frameworks" refers to some BIM-Blockchain application, and finally, Section "Safe BIM Certificate (Local Context)" provides results of a local survey addressed to BIM professionals that will be taken into account for proposing secure BIM certificate through atypical BIM education curricula, based on an interdisciplinary collaboration from three departments at Qatar University (Computer Science and Engineering Department, Architecture and Urban Planning, and Civil and Architectural Engineering Departments: CSE, AUP, and CAE) within a national priorities research program (NPRP7-1883-5-289 project).

State of the Art

The education sector, especially the HEIs, is still lacking to meet the industrial needs in terms of manpower for the construction industry. In terms of a national development, human resources represent a major factor, and its quality level depends on the society's awareness and understanding, which is also based on the quality of education and training (Yusuf et al. 2017). A better use of new technologies needs a high level of education, particularly technical education, to achieve productivity. Technology-based education system plays a crucial role in human resources development (Castells 1999). Meanwhile architecture and engineering became separate jobs from what we called in the past as "Master Builder". The education of the AEC disciplines' students have been changed in isolation manner from not only each other but even from the industrials where they have to be in order to improve their skills by training and cooperation. Pressman (2007) affirmed that many programs in the academia give students wrong expectation when they finish their studies, which is working as brave solitary designers. But integrated practice necessitates a rethinking of that notion. Academia has to teach beyond how to design and detail, to how to engage with and lead others, and how to collaborate within a professional carrier (Pressman 2007). In order to build a 3D intelligent model (BIM Model), it is critical to gather the design team at the onset unlike the classical practice. They will simulate the real project wherein the accurate quality of the model is related in a direct manner to the information and detail that can be added. This new technology is shaking the professionals' roles by creating positions which have never existed before, i.e. BIM coordinator, BIM manager, etc. Previously, tutors in higher education institutions refused to teach new technologies such as CAD software programs to students. According to Macdonald (2012), the refrain "we're not teaching students to press buttons" is continuously heard by lecturers who suppose BIM is just another CAD software. Nevertheless, they failed to

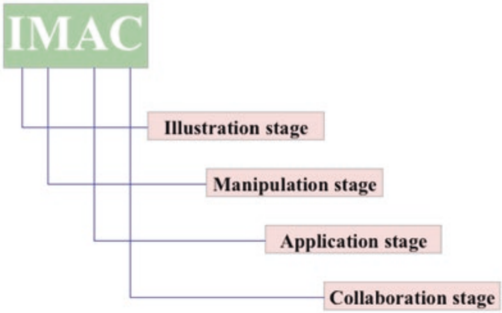

Fig. 5.1 The four stages making up the IMAC framework

realize that BIM is a technological process and it comes with plenty of advantages far beyond a simple 3D visualization to facilitate tasks and to transform culture. Macdonald (2012) proposed an education atypical of the BIM framework called the IMAC framework and which is composed of four stages: illustration, manipulation, application, and collaboration (Fig. 5.1).

The four stages mentioned earlier are as follows:

1. Illustration stage (knowledge/comprehension and receiving/responding): Here we are talking about a starting stage where the BIM models will be used to illustrate and demonstrate fundamental concepts to students. Those BIM models have a sufficient level of detail that allows lecturers/tutors to highpoint the different elements and objects showing how buildings will be constructed, insulated, and waterproofed, for example. Students will be taught separately in their proper disciplines.
2. Manipulation stage (comprehension/application and responding/valuing): In this phase, students begin interacting with and manipulating the existing BIM models by themselves. They will be prerequisite to make some basic changes and/or create simple elements and objects related to their disciplines within the existing BIM models. In parallel, students are developing their coordination working and improving their IT knowledge skills, in addition to enhancing knowledge related to their discipline-specific.
3. Application stage (application/analysis and valuing/organizing): Students at this phase, after having acquired the theoretical knowledge, start to apply it to solve problems related to their disciplines. For architecture students, they start to make the BIM models from sketching and learn how to set these models up for efficient interdisciplinary collaboration. Engineers thereafter begin to use tools to analyse those models using exports BIM formats. Construction managers will refine and improve the models with 4D (construction sequencing) and 5D (cost-estimation schedules).
4. Collaboration stage (synthesis/evaluation and characterizing): At this final phase, all the students meet and start to work on common projects. Real-project issues will be addressed by the students for solving. In order to facilitate the understanding of the process, the students would start working on semi-finished BIM

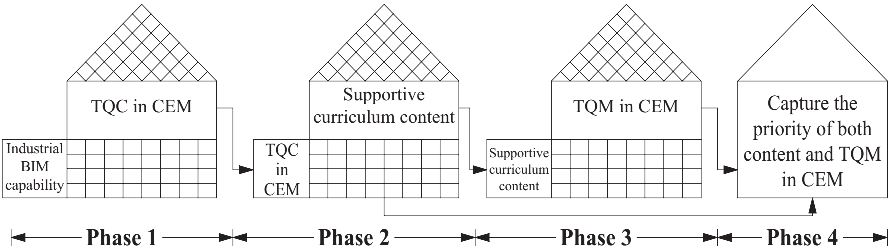

Fig. 5.2 Curriculum planning phases using the quality function deployment (QFD) method

models, and then be requested to make some modifications due to "new project information" highlighted. The students will learn the different types of contracts that smooth the BIM process and protocols, and they will continue to learn collaboration and coordination work.

Zhang, Schmidt, and Li (2016) identified priorities for successful curriculum development in civil engineering and management (CEM) utilizing quality deployment function (QFD) as a guideline, in order to respond to the increased need for talent development in the area of BIM in China. Indeed, adopted the QFD framework allowed to propose different curriculum planning phases which are described below Fig. 5.2.

Phase I is related to the planning curriculum, which highlights the industrial BIM capability for providing critical teaching quality characteristics (TQC), while phase II refers to the design curriculum, which gives TQC the priority to be included in the supportive curriculum content. In phase III, which refers to the implementation curriculum, teaching quality management (TQM) is attributed to specific curriculum content in civil engineering and management, and finally, phase IV concerns the priority curriculum, it is integrating phases II and III to provide curriculum content and TQM techniques and modules in order to meet the industrial BIM capability.

Wu et al. (2017) used virtual reality in BIM education curricula, wherein they designed and implemented two VR types: desktop-based and immersive, which are platforms called virtual BIM reviewer (VBR) in which students use the BIM model to highlight discrepancies by communicating with each other to arrive at problem-solving. The first VBR was presented to the Sky Classroom courses of 2015 and 2016 for evaluation and was used in 2017; the second VBR was added in 2016 with regard to the BIM model review procedure. Three issues were identified to test remote communication in class, i.e. low communicability, passive problem finding, and poor spatial cognition. The VBR functions have been tested in the Sky Classroom course to support seven universities globally collaborating in their course project. Manipulators in the desktop-based VBR explore the model through the virtual environment using mouse and keyboard, communicate with each other by the chat room, and interact through a server that includes the BIM model and client data. Users identify the design discrepancies and explore the BIM model utilising the inspection module, and then they discuss together to highlight those issues by using the communication module. They proceed to problem-solving using the modification module. Regarding the immersive VR module, it reinforces spatial understanding, so it gives them the best design issues identification. Notwithstanding the huge efforts to integrate an efficient BIM education strategy within higher education institutions, which intend to handle the lack of skills and equip graduates with specific BIM competency to meet the AEC industry requirements, we observed that it still remains insufficient and inadequate due to the new issues and needs related to information security that crop up and should be dealt with.

BIM and Security Issues

Implementation of BIM processes and protocols in many construction projects is definitely a major evolution for the AEC industry sector. All project's data-based BIM is shared electronically in a common environment (CDE), and using common data environment offers a consistent decisions basis through the lifecycle of a project, from design to destruction. However, some multiple new issues & risks are facing BIM adoption related to safety and security. consequently, the need to address cybersecurity awareness and implementation on collaboration systems and coordination processes is crucial. Cyber security goes beyond technology; it involves people, processes, and governance issues and their interrelationships. As BIM encompasses a complex interaction as well between the same actors, it is crucial that all personnel involved in a BIM project understand the cyber security implications (Boyes 2014). So, the problem comes from how to secure the sensitive data and how to manage the pertinent documents between interdisciplinary teams. From that point of view, we distinguish that there is less trust between different BIM actors compared with the traditional process information with plenty of singed and stamped and firmly bound pieces of paper. Such a complicated collaboration environment is generating automatically security issues. By using BIM, varied teams from the AEC sector are involved, and since that industrials do not have the same levels of security understanding and standards, they created those issues. Moreover, the change of the interfacing people and the growth of the supply chain during the project lifecycle make the protection of the information uncontrollable and more complex. Hence, the classical BIM skills become insufficient to master such issues, and we need to complete and compensate through new IT patterns and paradigms. Blockchain technology which is a cybersecurity feature would make the record even more trustworthy in a project common data environment (CDE), and the fact that all actions are recorded and visible makes a total transparency. The digital development of construction is going more speedily, after geographic information system (GIS), 3D Printing, BIM and Internet of things (IoT), it comes the Blockchain. this new technology used as fintech concept behind the cryptocurrency such as Bitcoin, Ethereum and all worldwide digital payment system (Brito and Castillo 2013). It allows trust in a business that lacks it. All businesses done in a blockchain environment are

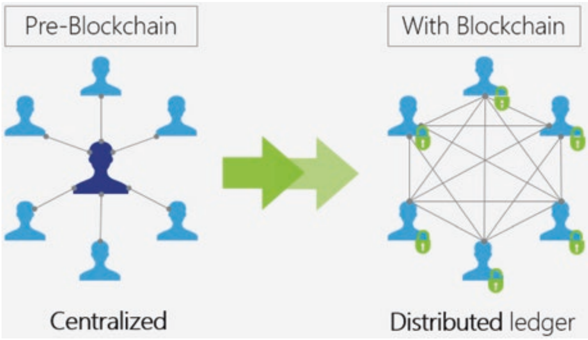

Fig. 5.3 Blockchain technology concept

recorded many times in the servers of all those given access, so nobody can break into the record and alter it without being obvious. The term "distributed ledger" is sometimes used to describe it, with each block of data solidly linked to all others in a chain of blocks. More broadly speaking, the blockchain enables a better tracking and administration of contractual documentation which cannot be achieved securely with BIM. Raising operational efficiency by digitalizing the storage of contracts in a secure manner is a big step forwards for the construction industry (Fig. 5.3).

Blockchain-Based Frameworks

Integrated through BIM processes and protocols, blockchain is representing a very powerful and promising tool that will make a concrete evolution in the AEC industry sector in the coming years. Blockchain technology is currently used in few domains but in different manner. For example, if we take its application in finance (Bitcoin, Etherieum, etc.), we realize that the number of transactions, number of participants, and size of the data to be managed are huge compared with those components in the BIM blockchain which are about hundreds of transactions between dozens of users up to a couple of gigabytes each. Turk and Klinc (2017) present four scenarios where blockchain would be used in a BIM process described below:

1. Chained and very decentralized: In this scenario, BIM files are linked into the blockchain which is already integrated across workstations of participants. All versions of all files are preserved and a valid "last" version of each file maintained via an operating system plugin.
2. Chained and slightly decentralized: due to the BIM files' big size in the first scenario, that exceeds the capacity of individual workstations as the entire Bitcoin does. This scenario comes with the distribution of the blockchain across a few key project partners in order to offer what is called a "wallet software". It appears to the client that a file is local while in fact it would be pulled from the blockchain and cached locally, if and when needed. At least one project partner

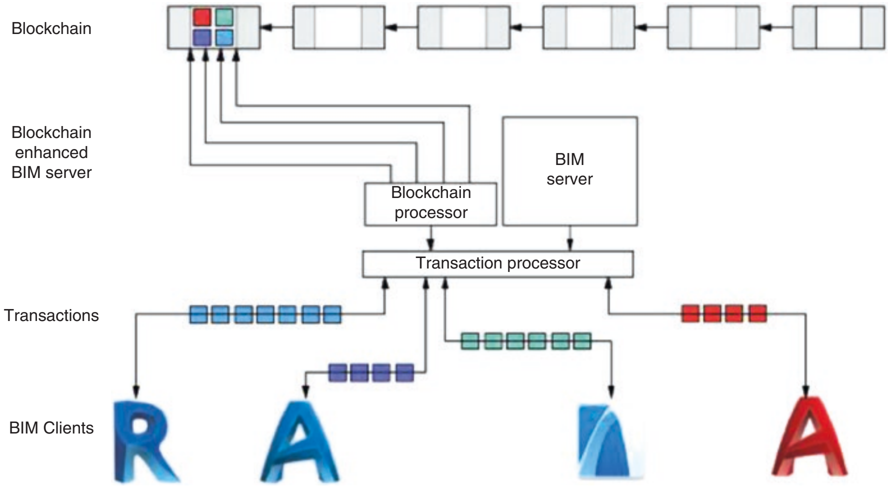

Fig. 5.4 Blockchain within BIM Transactions

has to host the entire blockchain. (3) Unchained: This scenario is completely different from the previous ones; it does not store the BIM files in the blockchain but only stores their fingerprints. It uses Cloud or Server to store BIM files. A copy of the blockchain is given to all project partners as poof to access the document management system. However, it would be left to other software to guarantee that all the files mentioned in the blockchain would be preserved at some location. (4) Blockchain of BIM transactions: In the last scenario, and in order to reach the best performance using Blockchain within BIM transactions, is preferred to integrate blockchain within a server where the size of a blockchain can be expected and better managed, as it is larger than the BIM data which are already controllable with current technology. The architecture of a system using Blockchain within BIM transactions is given here under Fig. 5.4, (figure enhanced by authors).

Blockchain is also used as a disruptive new technology at the urban level. Marsal Llacuna (2017) proposed Blockchain4Cities, where the main goal is to create a coopetition (physical–virtual networking environment). Physical actions executed by humans are registered in the blockchain and controlled in smart contracts. Blockchain4Cities is a Machine to Human system that permits the delivery and the implementation of urban codes. Blockchain-made urban policies codes: urban needs are submitted directly into the blockchain by citizens and the highly demanded ones are transferred to the authorities via consensus mechanism to include them in the official policies draft, and this will cover the real needs of the population unlike the political agenda. Blockchain-enabled urban planning codes: this is a continuity of the previous step; following the agreement on policies, their physical transformation is defined by using blockchain where citizens submit master planning's characteristics and zoning: this ensures a reasonable distribution of physical involvements.

Fig. 5.5 Blockchain4Cities

Blockchain-articulated urban regulation codes: this deals with the needs of citizens which are intangible and which are not transformable to physical involvements; utilizing the same pervious consensus. Blockchain-facilitated urban standards codes: this comes after all the above steps to design the standards requested based on the citizens' needs. Blockchain4Cities is a physical/virtual networking co-operation which allows the deliverance of urban codes using blockchain technology (Fig. 5.5), (figure enhanced by authors).

Mathews et al. (2017) highlighted that using Blockchain and BIM will resolve the issue of trust between different stakeholders in the AEC sector. They proposed an #AECoin cryptocurrency coin which is a collaborative consensus controlled by smart contracts within a blockchain. This helps micro- economies to be developed, recording transactions values of the collaboration and providing a method to reward both individual validations and contributions between all the actors by an agreed percentage of coin of that cryptocurrency. This system can radically change the current centralized professional collaboration existing today, allowing more trust to project-based multidisciplinary collaboration.

Cybersecurity/Blockchain Education Domains

Blockchain technology could be applied to other fields rather than only to BIM as mentioned earlier. It is possible to develop a similar concept covering those fields under an industry-integrated engineering education. Here follow some of those domains where the potential of blockchains technology can resolve issues related to.

Energy sector where there's firm belief that blockchains could offer solutions to the challenges that is facing this industry by enhancing the efficiency of current energy practices and processes, and by speedy developing devices' applications and digital platforms (Andoni et al. 2019). Decentralization and digitalization of the current energy system is one of the principal engagements where the sector is emerging; this requires the deployment and implementation of new patterns such as the distributed ledger technology which by its very nature provides a solution to the problem and a way out of the matter. The significant benefits from integrating Blockchains technology in the energy sector would enable reduction in transmission losses and allow people to trade energy among themselves under a shared economy system where energy exchange plays a huge role for the efficiency of our homes.

Another field where Blockchains technology offers a holistic potential in terms of decentralization, security, immutability, and privacy is the healthcare sector; from storing and sharing electronic medical records to personal healthcare data. Different Blockchain-based platforms deal with healthcare information exchange such as BlocHIE (Jiang et al. 2018) which is destined for storing and sharing data among medical institutions and patients. This platform is composed of three components: (1) the blockchain network where the collected healthcare data are stored, (2) clinics and hospitals where patients' diagnostic records are shared with other medical institutions through the Blockchain network, (3) IoT devices which share the daily routine healthcare data of individuals automatically in the Blockchain network. BlocHIE platform takes efficient care of privacy and transparency; when it comes to data shared from medical institutions, none from either side (hospitals/clinics or patients) can deny, for example, a medical treatment that was provided. Moreover, healthcare data shared from individuals would be used for future healthcare researches.

Safe BIM Certificate (Local Context)

The Qatari government anticipates spending around $160 billion on infrastructure and construction projects such as metro systems, stadiums, residences, and hotels, in preparation for the 2022 FIFA World Cup. (Qatar Construction Summit 2011). Ensuring the efficient delivery of those projects necessitates a total fulfilment of the requirements and specifications within a specified time. The implementation of BIM process thus becomes mandatory. Notwithstanding, an increase in the use of BIM has been observed in Qatar's AEC sector in the past few years. Indeed, large-scale clients such as Qatar Foundation, Qatar Economic Zones, Lusail Smart City, Ashghal, Qatar Rail, and the Supreme Committee for Delivery and Legacy require BIM implementation in their projects. Multiple efforts have been made to elaborate such BIM requirements and regulations for tenders to restructure the BIM processes and protocols. For example, Lusail Smart City is one of the BIM pioneers in Qatar due to its largest BIM projects (buildings/infrastructure) which have been used in many business processes as design and construction, marketing, etc. The Supreme Committee for Delivery & Legacy intended that the stadiums projects would be constructed totally the BIM way; their BIM Implementation Master Plan is a perfect specimen to be followed by any potential consultant/contractor interested in participating in these developments. Ashghal has also implemented BIM requirements in their projects such as expressways and roads, which generated a lot of benefits for all stakeholders. Such BIM requirements are projected to be adopted soon as standards for highway and tunnelling projects. However, the capability in providing a complete BIM processes implementation for the entire AEC sector is still limited. Hence, the necessity to tackle BIM needs becomes crucial and could be achieved by real awareness and BIM education programs. BIM education in Qatar is still scanty if we compare it with occidental countries such as England or the United States where universities have BIM post-graduate degrees (PhD, Master). However, most of the known construction's organizations are mainly focusing on BIM knowledge and deployment. Because of the rising security concerns mentioned earlier, it becomes necessary to deal with these issues. This chapter and with the support of the survey findings, proposes atypical educational BIM security curricula in the form of an industry-integrated certificate. It has the purpose of improving the level of BIM security competency and understanding among students and BIM experts.

The Survey

The questionnaire developed by the authors covers four parts including: (1) BIM professional's designation and the company that he/she works with as well as the accurate sector describing the area of work; (2) BIM experience of the company such as the adoption of BIM procedures and protocols, BIM investments and training, etc., (3) BIM obstacles faced and issues related to information security and (4) New IT patterns' application to BIM and the companies' interest to secure a BIM certificate at the Qatar University.

The established online survey was sent to 30 BIM professionals who are currently working or have previously worked in the region (contacts of the companies and firms from the different Qatari AEC industry sector). The respondents' survey answers represent their companies' viewpoint and philosophy to the BIM approach.

Data Collection

Among the 30 BIM professionals targeted, 18 were participants in the survey. However, three of the submissions were incomplete and were excluded from the analysis. It was speculated that one of the reasons the three withdrew was due to their lack of experience in BIM. The final response rate of this survey was 50% and the 15 complete submissions were analysed in this study.

Responses' Analysis

Three questions were asked in the first part related to the BIM professionals' contacts such as name, e-mail address, company, etc. Majority of the professionals are working in the Architecture domain (66.7%), while the Engineering and Construction fields represent (60%) and (53.3%), respectively (Fig. 5.6).

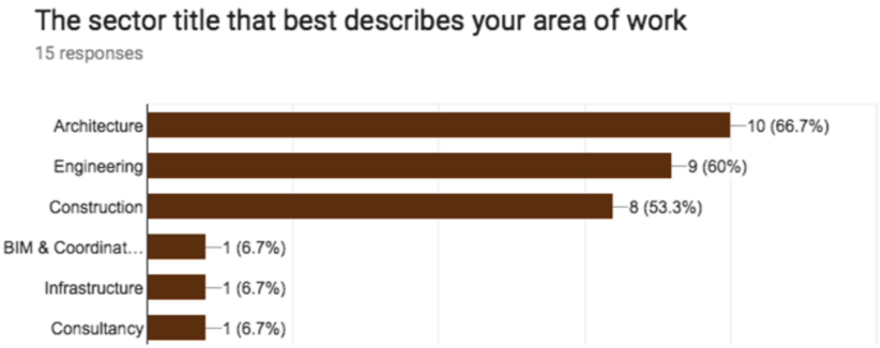

Fig. 5.6 Sector of Work

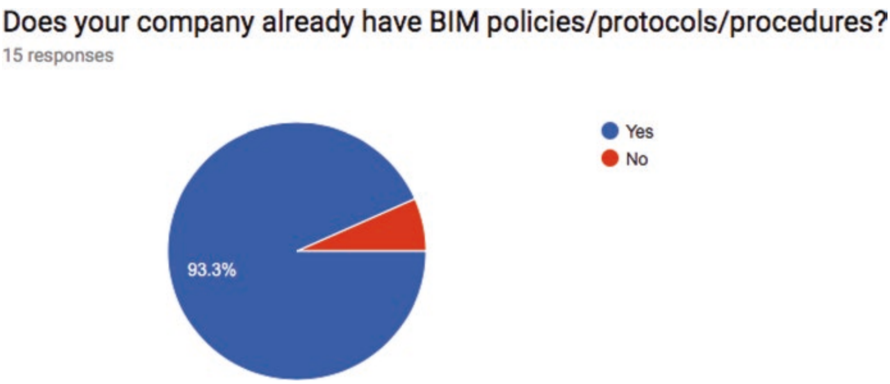

Fig. 5.7 BIM Awareness

In the second part of the survey (BIM experience of the company), five questions were addressed to the BIM professionals. The first one was in regard to the company's adoption of BIM. Its percentage totals to 93.3%, which points to the fact that majority of companies are conscious of the benefits of BIM in the design and operation processes (Fig. 5.7).

As far as the BIM key roles in companies is concerned, it was found that the most presented one is the BIM Manager (80%), which meant that he/she would play a pivotal role in implementing BIM processes and tools within the company. BIM Coordinator and BIM Modeler (26.7%) were next followed by the BIM Engineer (13.3%). New roles were also identified a related to the field such as BIM Director, Information Manager, etc. (Fig. 5.8).

One of the questions in this area was if the company has been conducting BIM training for its staff. Figure 5.9 shows that the majority invest on BIM software programs and on internal training (80%). However, consultants train companies' employees externally (13.3%). The training in general focus on: BIM Processes,

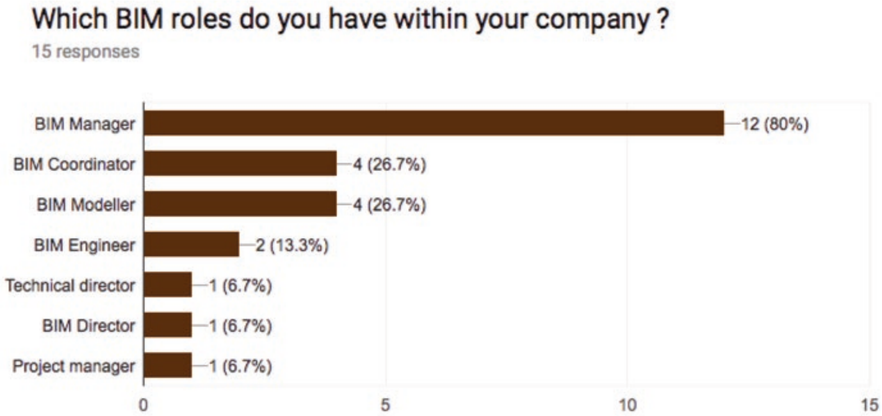

Fig. 5.8 BIM Key Role

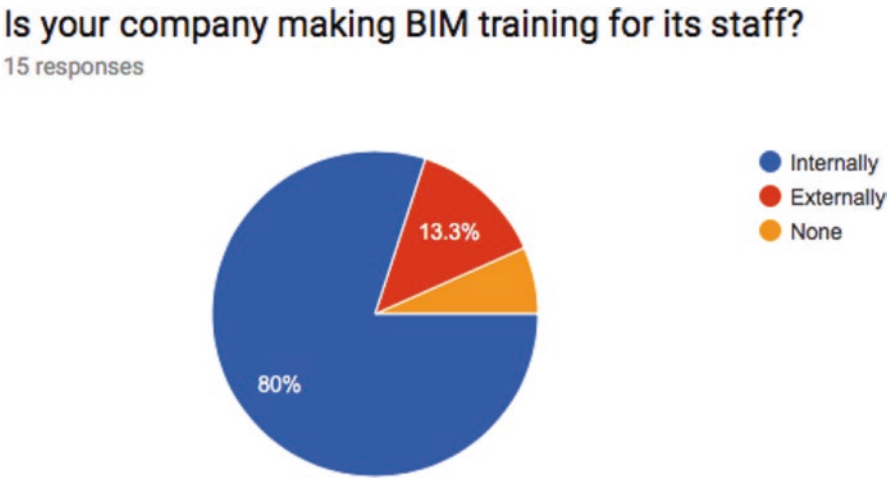

Fig. 5.9 BIM Training

Technologies, Policies, Standards, Contract Management, Drawing Production, Workflows & Clash Detection. Only a few firms do not train its staff because of limited budget, lack of skills, lack of awareness, etc.

The third part's questions highlighted issues and obstacles that the implementation of BIM faced. The responses were divided between limited budget and missing skills (26.7%) and (20%), respectively. Figure 5.10 shows other barriers such as change in management (20%).

Most of the companies use the common data environment (CDE) in order to exchange their BIM information and BIM model (86.7%); they also share information via meetings/e-mails and files exchange (53.3%), (60%), respectively (Fig. 5.11).

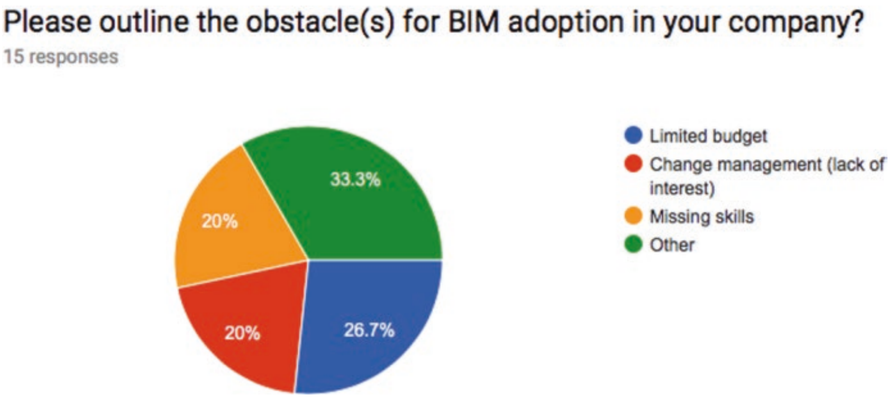

Fig. 5.10 BIM Obstacles

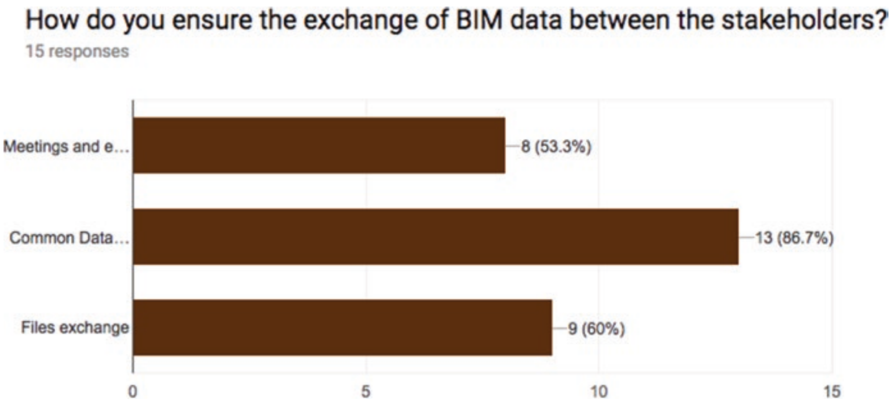

Fig. 5.11 BIM Data Exchange

One of the questions related to BIM security information was, i the information exchange secure enough or not between the stakeholders. Respondents considered security maturity related to BIM activities at both at a high and medium level (42.9% each). Only few respondents (14.3%) measured it at a low level (Fig. 5.12).

In the final leg of the survey, respondents indicated their total awareness of the developing IT patterns, i.e. cyber security technology–related to BIM. From Fig. 5.13, (93.3%) of answers agreed that a one-year university certificate on Secure BIM would be helpful to the AEC industry sector. The certificate includes BIM information security, blockchain technology applied to BIM, enhanced BIM programming concepts. Only (6.7%) disagreed and believed the certificate would not be needed.

Regarding companies' interest in securing BIM certificate at the Qatar University, as seen in Fig. 5.14, (80%) showed their interest in learning and undertaking the courses, while (20%) of respondents were not interested.

CO-OP option is prepared among three Qatar University (CSE, AUP & CAE) Departments and industry. All learners would reside alternately at the two learning

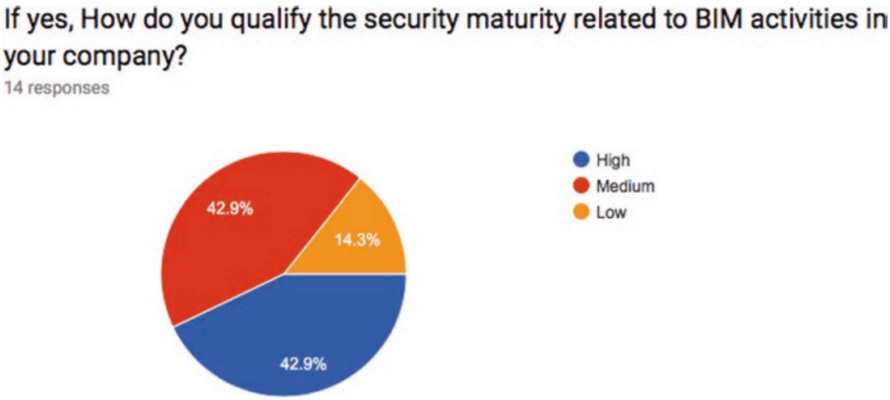

Fig. 5.12 BIM Security Maturity

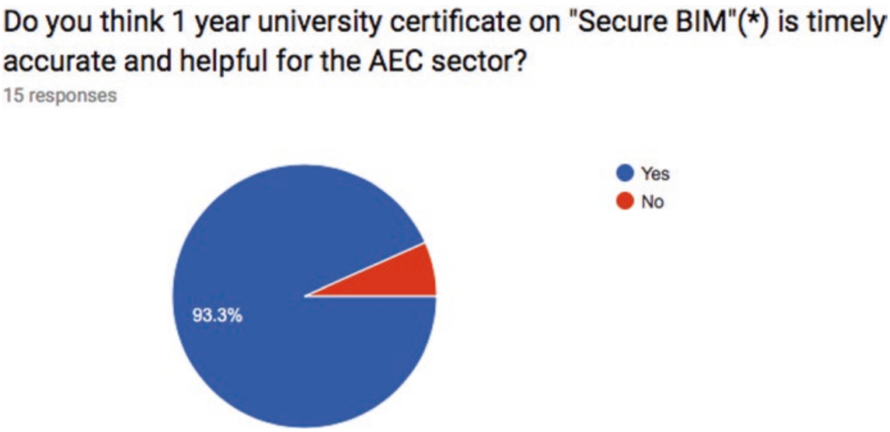

Fig. 5.13 Secure BIM Certificate Agreement

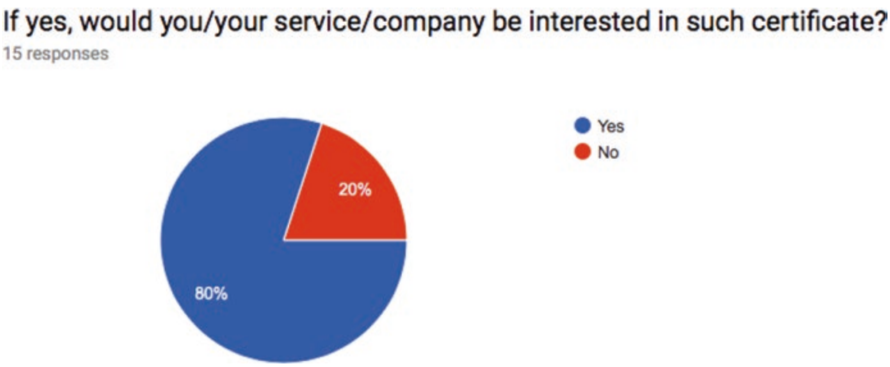

Fig. 5.14 Interest to Secure BIM Certificate

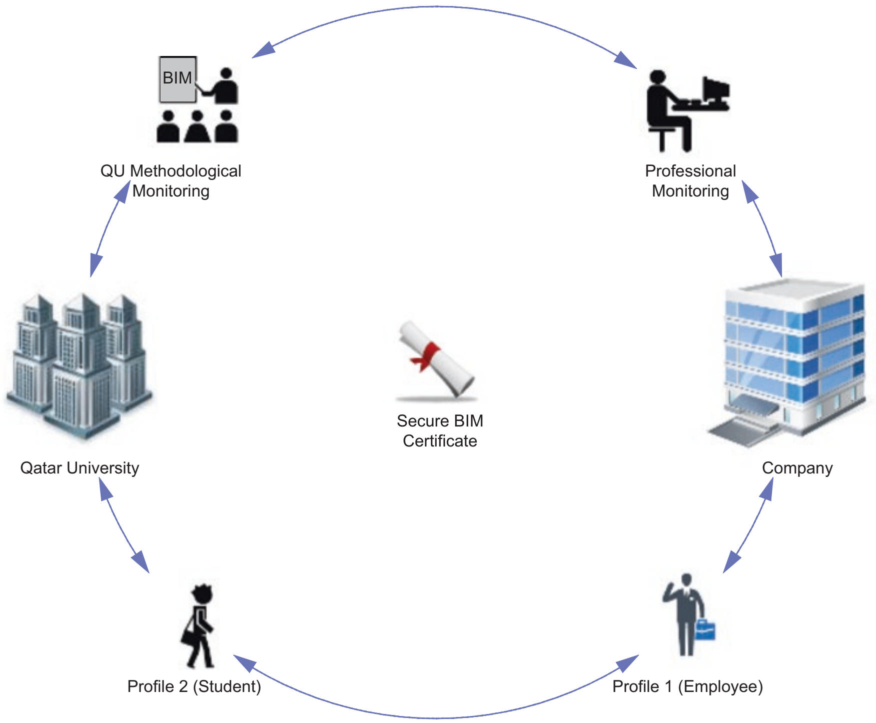

Fig. 5.15 CO-OP Option

venues, QU and the firms. Two learners' profiles have been proposed (Fig. 5.15) (Castells 1999)

Profile 1

The learner is already employed by the firms (employee). Firms have BIM-based projects or specific BIM tasks and would like to support the employee who is carrying out these tasks by a specific certificate. In the proposed certificate, QU would provide the courses and methodological monitoring, and the firms would provide professional monitoring and industry projects.

Profile 2

The learner is a young undergraduate (student) who is continuing his/her studies. Firms are keen to hire him/her as an employee, and interested in funding his/her internship for the duration of the certificate (1 year) within an assigned BIM project.

QU and the firms collaborate on the selection of the students. QU academic staff provide the courses and methodological monitoring. and firms provide the professional monitoring, industry projects, etc.

The proposed BIM certificate structure is given hereunder:

Duration: 1 year.
Number of Courses: five courses (see Table 5.1).
Course Project: one semester, Industry BIM-based project agreed on with the employer.
Monitoring/Coaching Sessions (QU wing): 1 day every 3 weeks.
Participant Engagement: the participant would work full time in the company.
Other Activities: seminars, workshops, brainstorming, etc.
Infrastructure: access to library and university facilities.

The new approach requires a closer interaction between the CSE/AUP/CAE departments and local partner firms, in order to select projects that meet the genuine needs of the industry, and that can be as beneficial as possible to the participant's learning. It also requires a reinforced dialogue between the participant, the firm, and the university tutors of the certificate degree.

In addition to these courses, leading experts would be invited to present specific topics in seminars and workshops. The certificate contains two courses from the CSE department and one course each from the AUP/CAE departments. The program covers a specific range of courses, such as Programming concepts, i.e. algorithms and problem-solving, programming, etc.), Information Security (Cryptography, blockchain fundamentals and application), BIM architecture software (Dynamo for Revit, Python, etc.), Model-based design (Scripts, Data sharing for Civil 3D) (Table 5.1).

In order to be more flexible for employees (learners), all courses are scheduled in late afternoons. The study plan requires learners to complete 12 credit hours (four concentration electives selected – Fig. 5.7). The normal duration of full-time study is 1 year (two semesters, where one semester is dedicated for the project). The total credit hours have been carefully designed to ensure complementarity and needed skills.

Table 5.1 BIM Certificate Courses

Course	Course title	Credit hours
Course 1	Applied Research Methodology	3 credits
Course 2	Programming Concepts	3 credits
Course 3	Blockchain- Based Computer Security	3 credits
Course 4	BIM Software	3 credits
Course 5	Model- Based Design Software	3 credits

Generic Conceptual Model

Industry-Integrated Certificate

As mentioned previously, blockchain technology can be applied to several domains where security issues need to be tackled. The Secure Certificate model proposed for BIM within Qatar University could be adapted and then be suitable for the other fields such as energy and healthcare and so on. The concept of multidisciplinary under the collaboration between Industry and Academia remains crucial. CSE department interacts with other colleges/departments i.e. (College of Health Sciences, College of Arts and Science…. etc.) in one hand and with industry (local partners organizations) in the other hand with regard to the secure certificate.

Figure 5.16 shows the secure certificate cycle, where the program includes two courses related to Cybersecurity/Blockchains technology provided from the CSE department:

1. Programming concepts, i.e. algorithms and problem-solving, programming, etc.),
2. Information Security (Cryptography, blockchain fundamentals and application).

Two other courses related to the filed which the certificate is destined for provided from the related colleges/department.

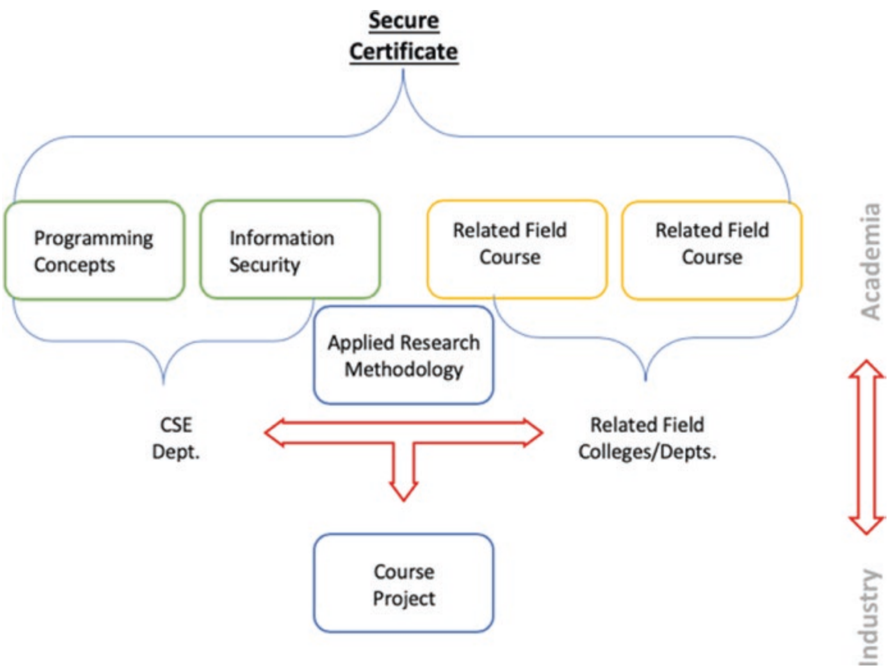

Fig. 5.16 Secure certificate cycle

Industry-Integrated Master

The program of the integrated master gives learners the opportunity to attain knowledge and advanced cybersecurity/Blockchains topics understanding. This enable them to apply new information and communication technologies patterns to real-world business environments and challenges or solve open-ended problems. Graduates of this program would be able to upgrade their knowledge with the latest advances in security technologies, frameworks, and methodologies. The program would also assist them to enhance and consolidate their information knowledge. The structure of the collaborative program would be as follows:

Duration: 2 years
Number of courses: eleven courses (see Table 5.2)
Course project: one semester, industry-based project agreed on with the employer
Monitoring/coaching sessions (at QU side): 1 day/month in the first year and 1 day/week in the second year
Participant engagement: full time
Other activities: seminars, workshops, brainstorming, etc.
Infrastructure: access to library and university facilities

Terms of reference for faculty consultancy (average consultancy workload: 1 day per week):

- Weekly mentorship sessions (1 h minimum on campus)
- Follow-up and virtual meetings (phone, Skype, etc.) with trainee and industry stakeholders
- Meetings with the participant on campus
- Meetings on-site with industry mentor and other stakeholders (three times per semester)
- Report guidance and evaluation
- Design of the project and methodology and follow-up on its implementation
- Professional development of the participant and transfer of knowledge and expertise

Table 5.2 Industry-integrated master courses

Course	Course title	Credit hours
Course 1	Seminar in Computing	1 credit
Course 2	Applied Research Methodology	3 credits
Course 3	Algorithm Design and Modelling	3 credits
Course 4	Information Security	3 credits
Course 5	Network Security	3 credits
Course 6	Related field	3 credits
Course 7	Related field	3 credits
Course 8	Related field	3 credits
Course 9	Related field	3 credits
Course 10	Related field	3 credits
Course 11	Master project	3 credits

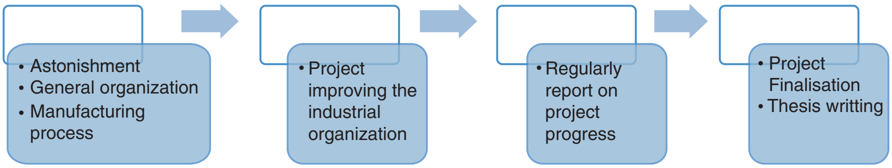

Fig. 5.17 Deliverable milestone

Deliverables

During the period of the internship, the learner is requested to deliver outcomes which are already validated by both QU academic tutor and company tutor, i.e. reports, progress project, professional thesis, etc.

Deliverables are detailed through the milestones hereunder where each phase is equivalent to 6 months (Fig. 5.17).

Tutors from both sides are also requested to deliver outcome reports regarding the evaluation of the learner during the whole period of the internship as well as the supervision of his/her professional project.

Deliverables are recorded among the two learning venues (university and company).

Conclusion

This article focuses on the current issues related to the safety needs in BIM processes and highlights new IT paradigm to tackle those needs. Based on the findings of the survey detailed previously, most of AEC companies in Qatar are aware about BIM security issues, and they show their interest to follow and undertake the typical BIM education curriculum, based on an interdisciplinary safe BIM certificate, to cover the gaps between industry and academia. Workshops, specific brainstorming, and seminars with the local industry and stakeholders are scheduled to assess and validate the proposal.

Moreover, this article proposes a generic model where blockchain technology could be applied to other fields rather than only to BIM. This model is proposed either for a 1-year certificate course or for a master's degree.

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Chapter 6
Exploring the Rotational Onboarding Programs for Early-Career Engineers in Practice

Bunmi Babajide, Hassan Al Yagoub, and Matthew W. Ohland

Introduction

In the USA, employers spent over $161 billion on employee training and development in 2017, and $362 billion was spent on training that same year (training industry) globally. This investment cost for a formal training program emphasizes the need to understand the training process and explore the different forms of onboarding programs. One of such programs is the rotational onboarding programs (ROP). ROP is a type of development program in practice that combines a job rotation approach with new employee orientation. The Corporate Leadership Council (2004) has indicated that rotational programs are popular among larger corporations where more than half of employers in the United States with more than 5000 employees have rotational training programs as part of their onboarding process. Onboarding has been attributed to desired outcomes such as job satisfaction, self-confidence, and career involvement for employees (Ashforth et al. 2007). Furthermore, companies provide onboarding programs because they believe employees are more committed to their jobs and are more comfortable in their roles when they go through the process of onboarding (Klein and Polin 2012). Onboarding, as defined by Klein and Polin (2012), is referred to as "all formal and informal practices, programs, and policies enacted or engaged in by an organization or its agents to facilitate newcomer adjustment" (p. 268). The duration of time for onboarding varies among organizations. According to Klein and Polin (2012), the onboarding process can take between hours to months to complete.

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Section A: Job Rotation Definition

Job rotation has been defined in different ways in the literature, for example, it is defined as “lateral transfer of workers among a number of different workstations where each requires different skills and responsibilities” (Mossa et al. 2016, p. 70). Another definition of job rotation is “the systematic movement of employees from job to job or project to project within an organization during the development of a task, as an approach to achieve many different human resources objectives, such as staffing jobs, orienting new employees, preventing job boredom or burnout, rewarding employees, enhancing career development, and exposing employees to diverse environments” (Wood 1995 as cited in Santos et al. 2017). It is worth noting that a job rotation differs from a promotion where the latter refers to upward movement in the organization rather than a lateral one that includes an increase in rank, job responsibilities, and compensation (Markham et al. 1987). Rotational onboarding programs have elements of all these definitions; however, for this study, we operationalize the definition by Huang (1999) that encapsulates the different aspects of job rotations covered under professional practice. A rotational onboarding program requires job rotations for a specified duration of time as a critical feature of the employee training process. According to Huang (1999), job rotation can be defined as a lateral transfer of employees among a number of different positions and tasks within jobs where each requires different skills and responsibilities. Individuals learn several different skills and perform each task for a specified time period (p. 75).

Section B: Rotational Onboarding in Organizations

Rotational onboarding is defined by Moreno (2011) as:

> A corporate program designed to hire recent college graduates into entry-level positions, offering them exposure to multiple areas in an organization through a series of 6–8 month assignments over a period of 18–24 months. Employees go through a job selection process for each new assignment and are evaluated on their performance at the end of each assignment. Salary adjustments take into account performance across multiple assignments. (p. 18)

ROPs are common practices within many sectors in practice. Sectors such as transportation, chemical, food and beverage manufacturing, finance, insurance, and real estate use rotational programs to onboard new graduate employees yearly. Some higher education institutions also offer rotational programs for employees with leadership potential. In the government sector, the US Office of Personnel Management (OPM) offers programs to several governmental agencies that model job rotation to prepare new federal government employees for new assignments and promotions. The use of ROP by multinational companies such as General Electric, Caterpillar Inc., Ford Motor Company, and others has made it a global approach to onboarding. According to the NACE’s 2016 Recruiting Benchmarks Survey of 233 employers from over 12 industries, one of the primary motivations for companies to offer such programs is to increase the retention of new employees (NACE 2016). The 1-year and 5-year retention rate of participants in such programs overall was 91% and 70.9%, respectively, versus 72.3% for 1-year retention and 59.8% for 5-year retention for those who did not participate in an ROP. Employers are using the ROP model to develop and retain candidates with high potential for success within their organizations (Frase-Blunt 2001).

The ROP typically requires that a cohort of new employees start a program at the same time. Even though they begin the program together, some experience multiple rotations in different departments at different times but the cohort of employees are connected with different forms of activities for the duration of the program. The duration of rotational onboarding programs also varies, but for most employers such programs (67.7%) have a duration of 1–2 years. Furthermore, each rotation lasts between 3 and 6 months for 75.8% of the surveyed employers (NACE 2016). The time and estimated investment in this form of onboarding are high, making it an essential process for companies and educators to understand what it is, how it works, and what types of competencies companies aim to develop in the workforce.

Section C: Rotational Onboarding in Engineering Practice

In the STEM-related disciplines, formal training and development of new engineering graduates are also offered at companies that offer engineering innovation and engineering services. Many employers require applicants for engineering positions at their organizations to have degrees from the Accreditation Board for Engineering and Technology (ABET) accredited schools. Also, many engineering programs at universities around the world are accredited by ABET that provides learning outcomes' guidelines for workforce preparedness. Although many companies have a form of onboarding process for engineering graduates, research that examines the onboarding process is scarce. In the engineering education literature, there is little research on the effectiveness of ROP, and the degree to which employers evaluate the success of such practice (Klein et al. 2015).

Even though training and development programs address the importance of education in engineering practice, it could be beneficial for engineering educators to consider how to improve the engineering programs at universities by exploring such programs (Katz 1993). While there is a wealth of information and studies on general onboarding, there is less research available on the rotational onboarding programs in engineering practice. This research study aims to explore rotational onboarding programs in 50 companies to understand the following: (1) the basic requirements of such programs, (2) explore competencies and attributes companies look for in early-career engineers for such programs, and (3) consider knowledge and skills companies sought to develop in early-career engineers through these programs. In the next section, we explore the literature from around the world about job rotation, onboarding, and rotational onboarding programs.

Section D: Job Rotation Benefits

Rotational programs have been studied from a human resource training perspective for professional development (Caligiuri 2006), career development of production workers' perspective (Zin et al. 2013), and employee motivation (Kaymaz 2010). Findings from research suggest that rotational programs can reduce safety incidents and cost of work-related injury, increase employee skills and job satisfaction (Jorgensen et al. 2005), reduce health risk factors (Mossa et al. 2016), and reduce boredom from repetitive tasks or lack of motivation (Azizi et al. 2010) in manufacturing settings.

Many organizations use job rotations upon the initial hiring of professional employees as an orientation instrument and a career development strategy (Wexley and Latham 1981). Sargent (1952) notes that job rotation can be a training instrument that stimulates the employee's development through maximizing the trainee's network while minimizing any friction that may cause personality clashes. Thus, the trainee focus will be on the competitive nature of the rotational program as the trainee would know they do not have a vested right in any particular position. Eriksson and Ortega's (2006) study indicated that job rotations could be used for employee and employer learning. Employee learning: those who rotate through different areas of a company have richer experiences than those who do not spend time in various departments, making it an effective career development approach. Employers can use job rotations to ascertain skills that an employee has and identify where they could be best utilized. On the other hand, some employers use such rotations as a means to enhance the employees' functional flexibility (Friedrich et al. 1998, p. 504). According to Kaymaz (2010) who conducted a study on the effects of job rotations in a professional setting, rotational training programs have a positive effect on employee motivation by decreasing monotony; increasing knowledge, skills, and competencies; and helping employees develop social relations with their colleagues.

Although the idea of job rotation and its effects on employees offer an insight as to the benefits of the practice, many literature studies on job rotations are focused on task-oriented operations conducted at assembly or manufacturing facilities and centered on current employees. According to Mossa et al. (2016), job rotation is used in the automotive industry in areas such as final assembly where there is a higher level of variation in assembly because customization typically happens in this work area. In such cases, job rotations are used to reduce potential health-related issues such as ergonomic risks of repetitive tasks (Mossa et al. 2016). Although a challenge to measure, boredom has been said to cause absenteeism, accidents, performance discrepancies, and a lack of job satisfaction (Azizi et al. 2010) and often characterized by feelings of agitation, irritability, and a desire to change the condition to a more motivating activity. Job rotations have been historically used in manufacturing to reduce these instances, reduce health and safety risks, and retain employees.

Although there are many benefits to job rotations, there are concerns of the reduction in skill development and mastery of job tasks when employees rotate through several areas. A study by Azizi et al. (2010) sort to develop a methodology to implement job rotation plans that can address boredom on the job in the manufacturing sector by optimizing job rotation practices but also reducing unintended consequences of such job rotation practices on employees such as a decline in skill improvement on one specific job task due to varied work assignments.

This study is specific to the aspect of job rotations that work in professional engineering settings and focused on the career development of new engineers referred to throughout this study as early-career engineers. In this study, career development will be defined as "an ongoing formalized effort by an organization that focuses on developing and enriching the organization's human resources in the light of both the employees' and organization's needs" (Byars and Rue 2000, p. 248 as cited by Patton and McMahon 2014).

Section E: Leadership in Rotational Onboarding Programs

This section is designed to explain how this term is used and operationalized in the context of this study. Many companies like Fiat Chrysler Automobiles and Praxair use the word "leadership" in their program name to distinguish it from internship and cooperative programs and from professional positions that are not geared for new engineers. For example, the Praxair program is referred to as the Leadership Technical Orientation Program, and Fiat Chrysler Automobiles calls their program the Leadership Development Program. These companies do not make a distinction between leadership and technical training in the program names. However, after a deeper look into the programs' websites and publications, our review suggests employers consider the combination of technical and professional skills development through the duration of their rotation as "leadership development."

Another reason why the word "leadership" is used in some of the onboarding programs name is to distinguish employees that are interested in a business leadership track from a technical leadership track during their career. For example, the Eaton Leadership Development Program has a specific program for master's/MBA degree holders. This research will focus solely on programs for early-career engineers who participate in an ROP as new employees. Lastly, leadership skill development in ROP goes hand in hand with skills development for engineers that can be considered part of professional skills needed to be an effective engineer (Farr and Brazil 2009).

Section F: Research Questions

It is important for engineering educators to understand what employers are doing to prepare new engineering graduates for their core business and to consider if rotational programs are successful models in which programs that lead to master's and doctoral degrees may implement. This study aims to add to the body of knowledge on engineering practice by examining the alignment between the knowledge and skills new graduates possess and what employers desire by the first day on the job. In addition, this study will help identify attributes engineers are expected to have when entering the workforce and what companies intend to train them on by the end of the rotational onboarding program. Since there are many opportunities for research in engineering practice, this research study will focus on a few areas. The following are the research questions designed to guide this research study:

1. What are the employer requirements to apply for rotational onboarding program in engineering practice?
2. What are the competencies and attributes employers look for in early-career engineers for such programs?
3. What knowledge and skills do employers sought to enhance or develop in early-career engineers through these programs?

Section G: Methods

In this case study, we employed document analysis to find evidence in the job description and program documentation of the skills and attributes employers seek in new early career professionals. According to Yin (2014), documents are units that can be analyzed. These could be letters, agendas, administrative documents, articles, or any document that is pertinent to the focus of a study. Some might argue that as informative as document content analysis is, it can lead to false clues in research when mishandled by inexperienced researchers (Tellis 1997). We believe, however, that it is an effective method to analyze information from multiple sources because it helps in structuring and making meaning of large data sets to draw inferences on a subject. We analyzed publicly available information from the company website and job postings available by the companies. This analysis was instrumental in understanding what skills and attributes students are expected to know prior to entering the onboarding program and those skills and attributes they can expect to gain during the rotational onboarding programs offered by the engineering companies, taking into account objectives of the program and several factors that make up the essence of the program.

Section H: Data Collection Process

Data was collected using information available from all 50 companies online. All data that describes the program was collected from several sources which include the company's website itself and job boards like LinkedIn and Indeed. Because job posts are seasonal, it was also essential to retrieve and save all job openings that match the onboarding program the company was advertising. The process used to collect the data includes the following:

1. A search was done on Google for the words "rotational onboarding engineers job." This search leads to several job posting sites like Indeed, SimplyHired, and Glassdoor.
2. From Indeed, several companies were found. For example, EnPro Industries, Lockheed Martin, General Electric, Caterpillar, and Rolls Royce were found. The keywords "rotation, engineering, and program" were effective in filtering companies that did not have rotational programs in their job offering.
3. From the step above, those companies were reviewed to verify that the companies did indeed offer a rotational onboarding program with multiple rotations.
4. Once confirmed as a potential company, the entire job posting is reviewed, and key elements such as company name, minimum GPA to apply, types of engineering discipline interests, basic and preferred requirements, roles and responsibilities, company size, and last early company revenue are recorded from the job posting.
5. The next step was going to the company website to verify the job posting and also add any additional information provided on the company website in the career section. All companies that offered rotational onboarding programs had information on their corporate site. This was used as supporting documentation to support key objectives of the program.
6. Once all the companies from this form of search were exhausted, a new Google search for "new engineer rotation program" resulted in a link from University of Pennsylvania career services titled "leadership development opportunities for engineers" with a list of 79 companies. These companies were then carefully studied through their website and links offered to see if they fit the requirement for this study.

Section I: Data Cleaning Process

Although there was an effort to collect all of the data in the Fall of 2017, there was more success in the Spring and Summer of 2018 to retrieve more information from job postings as employers anticipate new graduates will be graduating and looking to start their career after graduation. From the initial 75 companies found, only 50 met the requirement with job descriptions. Eleven companies were removed from the second round of data review because the program description had missed a critical information such as the duration of the program. Four companies were removed because they were focused solely on candidates with advanced degrees and not applicable to a bachelor's degree holder. These companies were excluded because the focus of the study is on early-career engineers who are transitioning into industry with no experience. Moreover, advanced degree holders could possess more years of experiences than a new employee transitioning into industry for the first time. Seven companies were removed because the job post had the word “rotation” and “engineering” in the description, but upon closer look it was found that they were part of a job description and not an actual onboarding program for engineers. Three companies of the jobs were postings that were interested in engineering or technology with no clear distinction or interest in engineering jobs only. In the end, 50 companies were selected for analysis for this project.

Main Findings and Discussion

Results and Analysis

The results of this study are placed in two sections: a quantitative review of the data and a qualitative one. In the quantitative review, the rotational programs’ minimum and maximum durations were compared relative to the companies’ number of employees and their revenue. When comparing the programs’ durations with company size, it was noted that the majority of the companies use the 2-year program model. Although the average length of time for a program is 2 years, the range was between 1 year and 5 years. All the studied companies with 1-year rotational programs had less than 80,000 employees as shown in Fig. 6.1.

The qualitative review was completed in two phases. The first phase discusses the job requirements of employers, while the second phase presents the overall results of what companies propose as their learning objectives for the rotational onboarding program. A typical average GPA required to apply for ROP was 3.0.

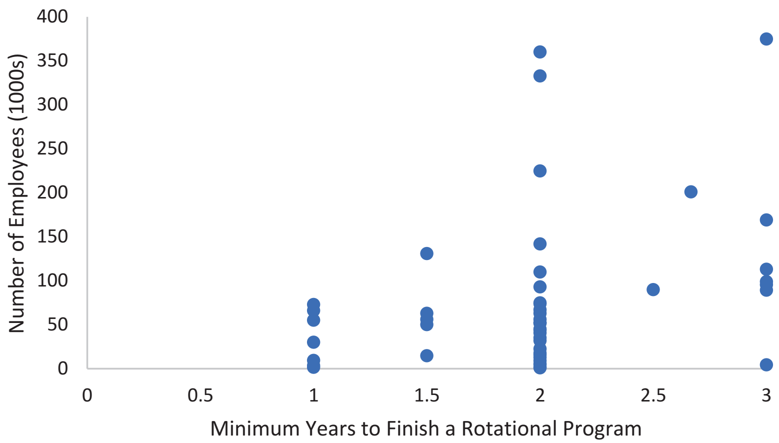

Fig. 6.1 The relationship between the minimum program duration with the company size

Job Requirements to Apply for ROP

In this section, we summarize a list of expectations that were listed to different rotational programs. Since this study is not a comparative assessment of various programs, we list the program descriptions as anonymous quotations.

(a) Adaptability

Several companies indicated their desire for candidates who could easily adapt to new working environments, "ability to adapt quickly to a new working location," and exhibit "an ability to learn quickly and adapt to a dynamic work environment."

(b) A degree program in engineering and GPA requirements

An accredited bachelor's degree in engineering was a key requirement that was clearly noted in some job postings, where companies listed the requirement of having a bachelor's or a master's degree in engineering from an ABET-accredited program. Furthermore, the majority of the companies studied demanded candidates for engineering rotational programs to have a GPA of above 3.0.

(c) Graduation date

The expected graduation date was also a major requirement for one-third of the companies studied. They expected candidates to either have graduated by a specific date, "Completing a Degree from an ABET accredited program in electrical engineering by June 2018" or having less than 2 years of work experience. This suggests that companies desire to hire those with less engineering practice experience to participate in their onboarding programs.

(d) Strong interpersonal skills

Nearly two-thirds of the rotational programs indicated the desire for candidates with strong interpersonal skills and leadership experience. This emphasizes that engineering rotational program candidates are expected to have strong interpersonal skills such as communication skills, leadership skills, and problem-solving skills and should be goal-oriented: "Outstanding people skills with the specific ability to successfully network, lead, and drive results on projects and teams." They should demonstrate critical thinking ability and systems engineering mindset to solve challenging problems and are expected to be involved with Formula SAE or similar extracurricular activities and have strong communication skills and the ability to work within diverse organizations. During the program, a candidate was to develop functional and leadership skills through a combination of formal training, mentoring and coaching, and, most importantly, on-the-job experience.

(e) Strong technical skills

More than half of the job descriptions indicated that companies desire candidates to have strong technical knowledge, mathematics skills, and problem-solving skills such as an expectations of "knowledge and understanding of analog circuitry (examples include Op-Amps, DC/DC power, Data Converters, sensing, etc.)." Other job descriptions reviewed included job knowledge expectations of drawing and schematic interpretation, product models, geometric dimensioning some wanted new engineering graduates with a working knowledge of programming language, “Programming skills in C/C++ (LabView recommended)” and computer-aided design programs mainly for electrical engineering graduates.

(f) Teamworking skills

Employers are interested in new engineering graduates who are self-directed and team oriented. Working on teams is part of the engineering practice dynamic and this is reflected in several job descriptions for the ROP. For example, an employer description states, “Ability to work in teams and collaborate effectively with people in different functions,” while another requires one who is “able to make independent decisions as well as operate in a team environment.”

(g) Willingness to relocate

Successful candidates were supposed to be willing to relocate to various parts of the world when the job demanded: “Geographically mobile: candidates must be willing and able to relocate multiple times within the U.S. and potentially complete an international assignment.” Willingness to travel was listed in more than half the surveyed rotational programs. This requirement involves visits to job sites, troubleshooting, overseeing manufacturing at other facilities, taking off-site training courses, and accompanying a salesperson to showcase new products to customers in various places in the world.

(h) Work experience

Job experience or internship for a certain period was an essential job requirement in nearly all companies: “The position requires zero to one year of experience. Also, one to two years of summer intern or co-op experience in an engineering environment is desirable. Previous exposure to design software is a plus.” Previous internship/co-op experience and proven ability to work on multiple projects and active participation in extracurricular activities and on-campus organizations.

(i) Work permit

Candidates were required to be US citizens or have legal work permits to work in the USA: “U.S. Citizen/Resident, Asylee, Refugee or have permanent/indefinite work authorization.” Applicants were supposed to have the authorization to work within the USA without restriction or sponsorship. This could create an issue of employability for international students who seek to stay in the USA to fill STEM-related fields as research shows that there is a shortage of workers in this sector. This requirement was not always listed in the job description since many American companies list this requirement in the job application.

Company-Proposed Learning Objectives for ROP

(a) Develop leadership skills

ROP participants were promised that they would learn to develop their leadership skills: "Consistent exposure to Senior Leadership." Candidates were to be introduced to senior management and gain leadership skills by attending regular innovation leadership forums and social events, designed to build a sense of community and camaraderie among the rotational program cohort.

(b) Expand technical skills

An ROP participant's development would be further supported by some technical and professional training opportunities: "…grow your technical expertise working with state-of-the-art technologies…." Candidates would explore career options and develop technical and professional decision-making skills.

(c) Expand networking skills

Companies said that they would expose an ROP participant to various programs and people and teach them networking skills: "Network with other professionals within many areas of the agency, training, skill development, and networking opportunities."

(d) Increase global exposure

An ROP participant may experience the entire engineering lifecycle from design, build, development and test, and gain a global understanding of how companies did their business. The following job description highlights such exposure: "the opportunity for a performance-based 6-month international assignment in one of our many technology research centers around the world." Thus, applicants are expected to contribute and be involved in real-world rotational assignments within different domestic and international locations.

(e) Increase the sense of professionalism

An ROP participant would increase their professionalism by applying engineering principles to task areas ranging from fundamental research on new processes and products to the development of work to improve and/or diversify existing product lines: "The goal of the program is for participants to fine-tune their skills, the program is a blend of both hands-on experience and classroom training courses…." Trainees would perform engineering assignments designed to develop professional work knowledge and experience.

(f) Networking with interdisciplinary teams

ROP participants were required to work with other employees to develop teamwork skills: "…partner with your fellow graduates to deliver your own design and manufacture project." Have the opportunity to work with outside suppliers, collaborate on cross-functional teams, interact with customers, and take rotations into other functional and geographic areas.

(g) Mentorship

ROP participants would have access to experienced mentors across the company who would engage participants in a wide range of learning experiences including mentoring: "Through coaching, mentoring and training with some of our best technical and business leaders, you'll develop technical and leadership skills." Candidates would experience coaching and career counseling with assignment managers and mentors who would provide the support needed to complete assigned projects.

(h)Life-long learning

Companies said they would help ROP participants complete their master's degrees in engineering: "…to allow you to complete your Master's degree at one of six Michigan universities." Furthermore, some employers offer company-sponsored learning experiences for new engineers by offering a lot of learning through the company-designed program that could earn them credits toward an MS degree in engineering: "Sponsorship and funding opportunity for continuing education for a technical Master's degree." Employers also propose to boost engineering graduates' career path by harnessing their ability and further develop their career through the flexibility in rotational assignments and learning opportunities: "Flexibility to discover your true passion and career path."

Discussion

Job Requirement

In addition to obtaining a degree in the field of engineering, most companies desire candidates with specific minimum GPA and other skills and attributes such as strong interpersonal skills, technical skills, and willingness to relocate, and in some cases, employers desire things such as a letter of recommendation from potential employees' college professor be presented during the job interview process. This section will explore these requirements.

GPA and Attributes

The result of this study supports the findings by NACE (2015) who conducted the Job Outlook 2016 survey report to understand what employers plan to consider when reviewing new graduate job applications during the 2016 hiring season. Two hundred one companies participated in the survey. A total of 71.4% of engineering service companies planned to screen new graduates by GPA. A 3.0 GPA was the median cutoff for engineering services. After GPA, overall, the next considered by all surveyed companies were attributes and skills employers screen as most important for new graduates to have. The top three skills and attributes were leadership 80.1%, ability to work in a team 78.9%, and written communication skills 70.2%.

Given that the leadership is desirable, the description of the engineering rotational onboarding programs also suggests that part of the goal of the program is to develop leaders through experiences in the program and by the assignment of upper management to mentor and nurture their career growth within the company.

Internship/Co-op Experience

The findings of this study also support the NACE (2015) findings that employers are interested in new graduates who have had previous work experiences such as internships and cooperative program experiences. Findings of this study also suggest that some companies give preference to those who had such experiences. Interestingly, most companies are not interested in hiring early-career engineers with many years of experience. Most companies in their job description state that an average of less than 1 year of experience in engineering practice is desired for engineering graduates to qualify for ROP positions. Noteworthy here is that employers do not make a distinction for engineering graduates with advanced degrees. Those with advanced degrees applying for the program are also required to have less work experience beyond internships and cooperative experiences.

Connecting ABET Learning Outcomes and Employer Expectations

In different regions of the world, employer expectation and new graduate skill gap have been a major area of discussion, and different employers from different parts of the globe express the need for better-prepared graduates (see Passow 2012). An example of a study of such research is the Middle East and North Africa (MENA) region. A study by Ramadi et al. (2016) suggests that there are significant gaps between managers' expectations in engineering practice and the skill set possessed by engineering graduates in the region, citing communication, time management, and lifelong learning as some of the most significant areas where employers in the MENA region felt they realized gaps in new graduates. The lack of preparedness for engineering practice is not peculiar to any region of the world. Indeed, these types of studies exist for many parts of the world. However, studies of competencies needed for engineering practice and employer's views are scarce in engineering education research for the MENA region (Ramadi et al. 2016).

A list of competencies necessary for engineering practice has been presented by ABET and several bodies of work (see Passow 2012), including the National Academy of Engineering report called the Engineer 2020 report which addresses competencies engineering graduates should possess for success in engineering practice. Several employers from this study require applicants for their program come from ABET accredited programs as an essential requirement for employment. This makes ABET learning outcomes a key aspect of engineering programs that engineering educators focus on for student preparation for work in practice. Because research that connects employer-desired skills, engineering curriculum, and how employers are bridging the potential gaps is scarce, it is important for engineering education research to continue to explore developmental training programs like the rotational onboarding programs in engineering practice. In so doing, engineering educators will move toward understanding potential gaps in engineering education that employers around the globe are seeking in early-career engineers and how the engineering programs can improve curriculum to continue to promote engineering student preparedness for work in practice.

Applications to Engineering Education Practice

To continue to develop our understanding of this form of onboarding and training program in engineering practice, we consider applications of rotational onboarding programs in engineering education in higher education settings through the curriculum and co-curriculum.

There is significant evidence for the benefit of worker flexibility, and the importance of cross-training personnel is heightened in environments where high workload imbalances are present (Davis et al. 2009). In engineering higher education, student enrollments represent a significant component of faculty workload, and shifts in the disciplinary distribution of undergraduate enrollment can result in a high workload imbalance. The "dot com bubble" resulted in a notable enrollment shift toward electrical and computer engineering programs. In response to those enrollment fluctuations, however, higher education engaged in a rapid growth of faculty in electrical and computer engineering as well as related disciplines (Stankovic and Aspray 2003). A study of supply and demand for information sciences faculty reports that "While the number of applicants remained fairly stable over the years, the number of openings increased by more than nine times between 1992 and 2000 before a sharp drop in 2001" (Frolick et al. 2005, p. 686). Although institutions responded to the bursting of the dot com bubble by slowing or stopping faculty hires, higher education already had an oversupply of teaching staff in disciplinary areas related to computing (Davis et al. 2005). The oversupply of teaching staff is exacerbated by the potentially long careers of academic faculty (Hicken 2013).

One response of electrical and computer engineering departments to the surplus of teaching staff, particularly at research-intensive institutions, was to increase the research expectations of those faculty. This addressed the oversupply both by generating research revenue to offset the resulting cost and by increasing the number of tenure denials. Research on managing workload imbalances suggests another solution: a rotational onboarding program in engineering academia would develop the cross-trained faculty needed to manage fluctuations in disciplinary enrollments. In a rotational on-boarding process, new faculty could teach a variety of lower-level courses so that they could be prepared to teach any of those courses subsequently as needed to balance demand. This approach is particularly relevant in engineering higher education today, when mechanical engineering programs are experiencing a period of significantly increased enrollments. Engineering administrators have learned from the earlier surge of faculty hiring in electrical and computer engineering, so mechanical engineering programs have resisted a hiring spree. As a result, they have suffered increasing student-to-faculty ratios. It might make sense for engineering departments to rotate new faculty through teaching all the “fundamental” courses – those in which students from multiple engineering disciplines enroll – first-year courses (which come in a variety of forms), statics, dynamics, thermodynamics, and others. The implementation of this practice is hindered by the over-specialization of those courses, however. It is common for colleges of engineering to feature discipline-specific versions of dynamics, thermodynamics, and other courses. If the core of those courses were taught to students of multiple disciplines and supplemented by a shorter discipline-specific course, the system would have more flexibility, and a larger cohort of faculty could be capable of teaching the more general course.

Another form of “job rotation” is already practiced in engineering higher education. New tenure-track faculty at research-intensive institutions typically receive course release for a limited time to get their research program started while they focus on teaching fewer classes. In some cases, new faculty have an entire semester with no teaching. This practice might be described as a limited form of job rotation in which new faculty have an opportunity to focus on research more intensely for a time.

Conclusions

There are several requirements to apply for rotational onboarding programs in engineering practice. Some of them include adaptability, minimal years of experience, technical and interpersonal skills, work experiences such as cooperative education and internships, willingness to relocate, and ability to work with teams among others. The combination of these requirements is found in the ABET criterion for engineering programs which is also specified in many job requisitions for applicants to have graduated from ABET accredited schools. Another aspect is that employers on average are looking for above average graduates who have the potential to become future leaders in technical capacity.

The objectives of the rotational onboarding programs in engineering practice are designed to enhance an engineering graduate’s undergraduate experiences by providing an experience that seeks to enhance and develop knowledge and skills such as leadership skills and life-long learning; expand technical skills, networking skills, and professional exposure; increase professionalism; and offer professional support through mentorship. These key objectives of these programs align with some of the key objectives of engineering programs in universities that adhere to the ABET learning outcomes criteria. More research work is needed to continue to explore these types of onboarding programs because all of the key areas of the program can be seen as an independent topic for research.

Implications

The study has implications for engineering education researchers and academia. With the publication of NAE Engineer 2020, part of the goal of engineering programs is to prepare engineering students for work in engineering practice. Exploring what employers are doing in their training and development program is essential to help inform potential program improvement and ensure that teaching methods are in alignment with employers' expectations. Additionally, because researchers seek to understand experiences of early-career engineers to inform on the impact of the engineering program curricular, it is important to consider the role of this form of training program during transition into practice that could have influence on how early-career engineers respond to academic research surveys and interviews. Academic research surveys and interviews on early-career engineers are important to the field of engineering education, and having enough information on interventions like ROP has implications for how we categorize skills and knowledge development of early-career engineers. In summary, this study has implications for academia to understand what employers are doing to prepare new engineering graduates for their core business and to consider if rotational programs are successful models in which graduate engineering programs may implement. It also has implications for employers to understand the alignment of what knowledge new graduates have by ABET standards. This study adds to the body of work in engineering education research that seeks to identify attributes engineers are expected to have when entering the workforce.

Future Direction

To continue to develop our understanding of this form of onboarding and training program in engineering practice, planned future work for our team includes exploring the influence of mentorship in rotational onboarding programs for early-career engineers, exploring how rotational onboarding programs promote the development of knowledge and skills for new engineering graduates. Also, in connecting this form of onboarding and training to higher education, we plan to explore some of the components and ideas of rotational onboarding programs in engineering education as far as curriculum and instruction are concerned. Furthermore, we plan to explore

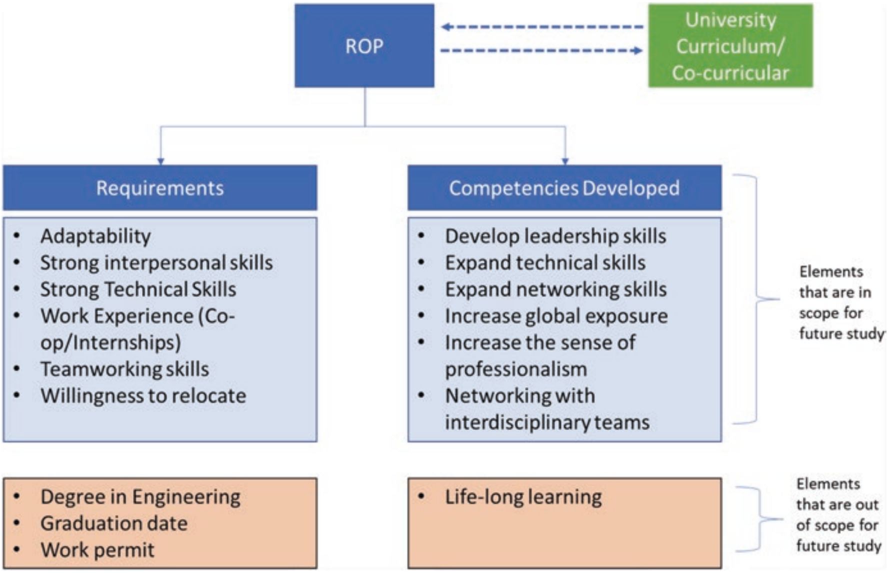

Fig. 6.2 Future work scope for exploring the ROP model in engineering education

how concepts from ROP can be applied in engineering classroom instructions. In our future work, we will consider which elements of the rotational onboarding program model are present and which ones can be potentially adopted in engineering education curriculum and co-curriculum. To guide the process of inquiry, we will consider the requirements and specified competencies development aim of ROP (Fig. 6.2). The components of ROP that will be out of scope for the exploration will be areas that are outside of academic life and do not pertain to student experiences such as work permit and life-long learning.

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Chapter 7
Reverse Engineering and Straightforward Design as Tools to Improve the Teaching of Mechanical Engineering

Eusebio Jiménez López, Mario Acosta Flores, Gabriel Luna Sandoval, Baldomero Lucero Velázquez, Juan José Delfín Vázquez, and Luis Andrés García Velásquez

Introduction

There is a great and growing necessity of people with knowledge of technology, capable of developing solutions for problems of the modern world oriented technologically (Verner and Greenholts 2017). In today's market, product companies are constantly looking for new ways to shorten delivery times for the new product developments that meet all customer expectations. Reverse engineering is considered one of the technologies that provide business benefits by shortening the product development cycle (Raja 2008). The ability to apply the reverse engineering to a product has been important during the time that the technology has existed. A vital activity in most branches of the industrial design and the production has been to acquire samples of the products sold by the competing companies and separate them. Understanding the engineering carried out by competitors' opponents can shed light on the strengths and weaknesses of their products, reveal the engineering ideas behind the characteristics of their products, and fertilize and further improve the innovation that occurs in the company itself (Lysne 2018).

Reverse engineering is a strategy of common design in the industry. It is a concept that in literature has come to encompass a wide variety of engineering and design activities; however, in its basic form, reverse engineering is simply the

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process of extracting information from a product from it (Curtis et al. 2011). Reverse engineering is a process that is used in several domains, such as mechanical engineering, electrical engineering, computer science, etc. (Ali et al. 2013).

On the other hand, to form people with the necessary competences to give solutions to the problems faced by companies, it is necessary that the engineering education implement or develop new methods or procedures through which the students can have systematic access to scientific knowledge and to the technological applications (Jiménez et al. 2013a). Reverse engineering and the process of direct design (a process that usually starts from an idea or need toward a model or finished product) are two methods that are commonly used in engineering education (Luna et al. 2011) and which are currently employed in various universities to reinforce the skills and competences of engineers (Beamud et al. 2017).

Reverse engineering is not a new concept in engineering education. In the past, this technique has been implemented in various design courses (Conwell et al. 1993). Generally, the students arrive with pieces of equipment, computer, software, or even chemical processes to be examined. Through reverse engineering, the students achieve the knowledge required to design their own equipment, computer program, or chemical plant. Reverse engineering forces students to progress to the upper levels of Bloom's taxonomy: design, implementation, and evaluation (O'Brien and Abulencia 2010). The process of product dissection (disassembly) has become a popular way to teach students about engineering concepts and design principles associated with engineering products (Chattopadhyay 2017). This reverse engineering process helps the students of the design teams to learn how the product and its functions and how the parts or subsets interact with each other.

The process of direct design, commonly described as the process opposite to that of reverse engineering, is also applied in learning in engineering. For Katehi et al. (2009), engineering design has to do with the design and creation of man-made products and is a process to solve problems. The design process is proposed by Yu (2016) to understand in a better way the mathematics and science under the concept of STEM (science, technology, engineering, and math).

Several authors have proposed different processes of the direct design (Pahl and Beitz 2007; Ullman 2003; Eggert 2005), in order to guide the development of products. In this way, both reverse engineering and the process of direct design are tools that help students to solve problems in the field of engineering and at the same time are methods that are applied daily in companies.

On the other hand, in order to potentiate learning in the study of engineering, it is necessary to incorporate, in addition to the methods of reverse engineering and direct design, models or pedagogical approaches that allow students to acquire the necessary competences to solve problems. During the last decade, there has been a change in the education in science, technology, engineering, and mathematics, especially in engineering, toward a pedagogy based on competences (Henri et al. 2017). Competency-based learning is a form of instruction focused in the results in which the students' progress toward more advanced work to dominate the content and necessary prior skills (Henri et al. 2017). The competency-based approach or the pedagogy of competency-based education (EBC) is used by various universities, either as a pilot program (Monat and Gannon 2018) or as an already established educational policy (Anderson 2018). There is no structure or model defined for CBE for higher education in general, only broad concepts of how and why a teaching model can be effective (Monat and Gannon 2018).

Within the EBC, the active methodologies are relevant for the teaching of engineering. Active methodologies are understood as those methods, techniques, and strategies used by the teacher to convert the teaching process into activities that encourage the student's active participation and lead to learning (Labrador and Andreu 2008). Some of the active methodologies used in education are (Prince and Felder 2006) problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching. Active methodologies are used in the teaching of engineering. For example, Tembe and Kamble (2016) apply a combined use of conceptual mapping and techniques of online course modules as part of the course of internal combustion engines. The results show that student performance improves using active learning methods. One of the techniques used in active learning is the project-based learning, since it is a significant and experiential learning process that helps students become active learners by providing real-world problems for them to solve (Hmelo 2004).

So that the learning can be active and meaningful, it is necessary to develop in the students generic and specific competences, equivalent to those that are used daily in companies, because in this way the projects would be carried out with more motivation and significance. For this reason, it is necessary to create procedures based on reverse engineering and direct engineering that allow the students to develop projects that involve more challenges, complexity, and more industrial context.

This paper proposes procedures for the systematic measurement of parts and components from the perspective of reverse engineering and a direct design process composed of nine phases, through which engineering students can develop projects that involve educational and industrial considerations. Some examples and experiences about the applications of the procedures are described; one of them is developed through project-based learning.

Reverse Engineering: Conceptual Proposal

Reverse engineering constitutes a long-standing discipline that has long been a tool available for technological progress. It is possible to define reverse engineering as the process to obtain, from all human creation, lost fragments of knowledge, ideas, and design philosophy when that information is not available, either because its owner does not want to share it or because the information in itself has been lost or destroyed, in other words, the process by which an artifact designed from an engineering method (such as a car, the turbine of an airplane, or a computer program) is decomposed in a way that reveals its internal details, such as its design and architecture (Eilam 2005).

There is no general definition of reverse engineering, because each author defines it according to the field of study. For example, Sreeram et al. (2016) describe the reverse engineering with the general name of digital technology of the CAD (computer-aided design) model, the technology of reconstruction of the geometric model, and the manufacturing technology, which is different from the creation of the traditional geometric model. Reverse engineering is a method of analyzing a component for the creation of a copy or its documentation (Sokól and Cekus 2017). For Verner and Betzer (2001), reverse engineering is the investigation of an existing technological system with the purpose of revealing its design solutions and the development of an improved or new system. Consequently, the essence of reverse engineering is the analysis of the system dividing it into functional components and discovering how the relationships between the components provide the overall functioning of the system.

With the purpose of generalizing the concept of reverse engineering, Jiménez et al. (2013a) propose the following definition:

> *Reverse Engineering is the systematic application of a guided analytical – synthetic process with which seeks to determine the characteristics, properties and/or functions of a system, a machine or a product or a part of a component or a subsystem. Its main purpose is to determine at least one model or characteristic of an object or product or reference system whose information is limited, incomplete or does not exist.*

The above definition is more general than those presented by Sreeram et al. (2016) and Sokól and Cekus (2017) and can be used to propose the following phases:

1. Phase 1: Initial research and formulation of the problem of reverse engineering.
2. Phase 2: Analytical—synthetic development of the reverse engineering and determination of the equivalence B ~ A, where B is the model or characteristic of the object of reference A.
3. Phase 3: Evaluation and applications of the process and the results of the reverse engineering after the determination of B ~ A.

These phases systematize the process of reverse engineering, from the preliminary study of the object of reference (A), which can be physical or virtual, a problem to pose, a program, etc., until its formal study based on programs and procedures (P) in such a way that it is possible to determine a model (B) or characteristics with which it is determined that B ~ A. To achieve equivalence between model B and reference object A, the formalization of criteria is required, which for the case of duplicates, they can be geometric, dimensional, manufacturing, use, etc. Phase 3 proposes a reassessment of model B, since information generated to determine B can be used for various purposes.

The phases described previously are represented in steps:

1. The object of reference A is presented and analyzed preliminarily.
2. References are defined.
3. The objectives are defined.

4. The problem of reverse engineering is formalized.
5. With the references and with the objectives, a set P of analytical program (PA), synthetic program (PS), and equivalence program (PE) are designed.
6. The PA and PS programs are applied to reference object A.
7. A representative model of B^R of A is obtained.
8. The PE programs are applied to B^R and the reproduced object B is generated such that B ~ A.
9. The conclusions are given.
10. B is revalued, such that B ~ B^{VA} (where B^{VA} is the model B with added value).
11. B^{VA} is applied for various purposes.

This new proposal of definition and method of reverse engineering allows the following:

1. A greater scope in terms of applications of reverse engineering.
2. It gives importance to the preliminary study of the object of reference.
3. It systematizes the process of reverse engineering through programs and procedures.
4. Criteria are provided to determine the equivalents necessary to finish the reverse engineering.
5. The product or result (model) of reverse engineering is analyzed beyond its main objective.

One of the most important stages in reverse engineering is one in which the program or procedures are designed (number, type, and sequence of application) that must be applied to the reference object. The effectiveness of the application of the reverse engineering depends on the correct design and application of the procedures. There are three types of programs: (1) analytical, (2) synthetic, and (3) equivalence. The analytical programs are used to know or determine the basic properties or characteristics of the reference object. The synthesis programs take the information from the analytical programs to generate the models of the reference object, among them the representative object (raw model). The equivalence programs are used to determine if the representative objective complies with the objectives set and in this way establish the operational equivalences between the reference object and its duplicate.

In relation to the engineering education, the proposal for the definition of reverse engineering proposed by Jiménez et al. (2013a) allows to extend the applications, since the object of reference cannot necessarily be a component or machine. It is even possible to raise problems in engineering with the reverse engineering, since in general the problems are formulated with little information, and during their planning and development, little by little the information is generated until the problem is resolved. Figure 7.1 shows a conceptual map of reverse engineering, its phases, and its steps.

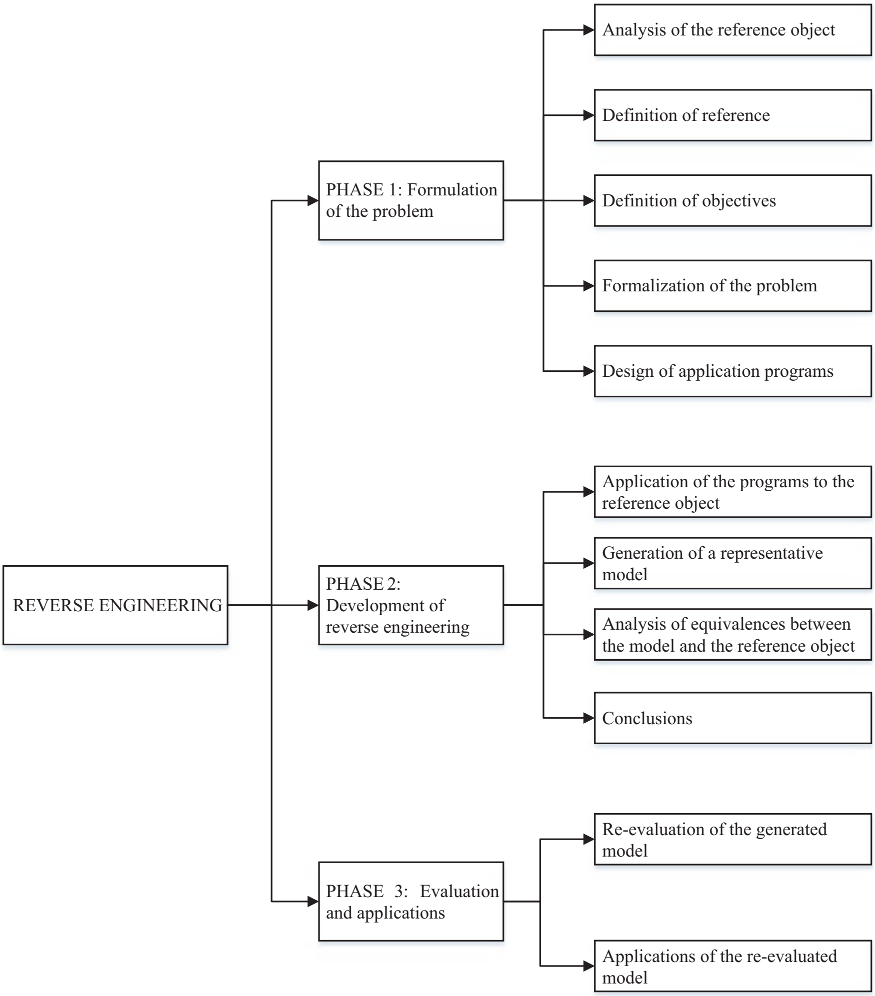

Fig. 7.1 Conceptual map of the reverse engineering process

Methodology for Direct Design or Design Process

Direct engineering, like reverse engineering, is used as an auxiliary method for engineering learning. Because direct engineering is usually part of the customer needs and ends in a prototype or machine, design intentions can be very vague at first and then evolve as the design process develops (Mitchell 1993). The phases of the direct design or design process are not unique, for example, Pahl and Beitz (2007) propose the following steps: (1) clarification of the task, (2) conceptual design, (3) design body, and (4) design to detail. Ullman (2003) proposes the following phases: (1) development of the specifications/planning, (2) conceptual design, (3) product design, (4) production, (5) service, and (6) product withdrawal. Jiménez et al. (2013a) propose the following nine phases: (1) analysis of client requirements, (2) conceptual design, (3) design body, (4) design to detail, (5) manufacturing and assembly, (6) testing and validation, (7) industrial transfer, (8) analysis of the life cycle of the product, and (9) technological innovation.

The proposal of phases of product design provided by Jiménez et al. (2013a) is similar to that proposed by Ullman (2003); however, the first proposes a close relationship with the client during the design process and provides a practical sequence and operation for the learning of engineering. The following describes each of the phases of the design process proposed by Jiménez et al. (2013a).

Phase 1 consists in establishing a relationship between the designers and the client, in such a way that it is possible to define the greatest number of requirements and generate a cotization and a work plan as soon as possible, so that once the quote is approved by the client, proceed to formalize the project in a work contract.

Phase 2 consists in systematically developing the conceptual design taking as reference the proposal defined in the work contract. Ideas and proposals are discussed that allow to determine the functionality of the product or system designed. Preliminary CAD models are generated and potential prototype proposals are simulated, including queries to material databases and preliminary engineering. In this phase, the client is taken into account, since there is a possibility of changes in the original proposal that may increase or decrease the costs or changes in the committed times. The objective of the conceptual design is to validate the development proposal described in the work contract.

Phase 3 refers to the design body that consists of validating the conceptual design proposal based on analysis, calculations, and simulations. The theories and methods necessary to determine the relationships between the subsystems or parts related to the proposed design are applied. Materials are selected and critical design conditions are analyzed. The necessary adjustments are made to the conceptual proposal and all the analysis information is generated and concentrated.

In phase 4, the design, its modeling, and calculations are transformed into fabrication and manufacturing, generating the manufacturing plans, which are of great importance for the manufacture of the components. In fact, manufacturing plans represent the design of a product in terms of manufacturing. The design is completed by considering all the missing details that were not taken into account in the design body. The result of phase 4 is the geometric and manufacturing information necessary and sufficient to conceive physically by means of fabrication the design of a machine prototype.

Phase 5 consists of transforming manufacturing plans into physical parts and components, by means of machines and tools, and manufacturing systems. If manufacturing is done with suppliers, it is always important to carry out all planning and supervision in order to have the pieces in time, form and quality. Subsequently, the components are assembled and the necessary adjustments are made. The objective of this phase is the physical generation of the product or prototype.

Phase 6 consists of the application of validation tests to the prototype or product. The prototype is studied with the information and the requirements of all the previous phases in order to verify whether it meets with the design specifications. This process determines if the prototype is valid or if it is not. In case it is validated, a plan must be designed to transform the prototype to a machine that consists of a new analysis and studies where the design for serial production is prepared. The product obtained will then be validated and therefore the prototype is machine transformed. In case it is not validated, the prototype must be redesigned until the objective is achieved.

Phase 7 consists of transferring the machine to the customer. A technological package consisting of technical reports, manufacturing plans, and materials list is prepared. An operation plan of the machine, an installation plan, and a maintenance plan are generated. The project is closed and the terms of the warranty times are analyzed.

Phase 8 refers to the process of monitoring of operation of the machine throughout its life cycle for which it was designed. The client is in communication with the design team in case the machine presents problems, in order to solve them or modify the design if necessary. After the expiration time of the guarantees, the team of designers and the client monitor the machine so that it is possible to have as much information as possible during the life cycle.

Phase 9 refers to the designers, using the information from phase 8 and consulting customers and markets to improve the machine or system, so that it can adapt to new requirements. The innovation of the machine can be gradual although sometimes it tends to be radical. Generally, in this phase, new prototypes are generated based on the original machine information.

It is worth mentioning that each phase of the nine phases of the design process proposed by Jiménez et al. (2013a) is systematized by steps, which can be consulted in Jiménez et al. (2013b). It is possible to describe some of the benefits of the phases described above for engineering students during the development of their projects:

1. Learn the relationships between developers and the client during the design process.
2. The students know all the documentation that is generated during the development of a project (e.g., quotations, contracts, planning, guarantees, technological packages, etc.).
3. They learn the differences between the development of a prototype and the development of a machine.
4. They learn to document the designs in terms of manufacturing from the quote of the client to the technological innovation of the product.
5. Understand the importance of the transfer of the machine to the client and develop all the necessary documentation, such as the maintenance plan, operation plan, training, calibration in plant, and start-up of the machine or system designed.
6. They understand the importance of following up the operation of the product in the plant and the process of developing new products from the original design.

The application of the phases described above to the learning of mechanical engineering, particularly in subjects such as engineering design, design of machine

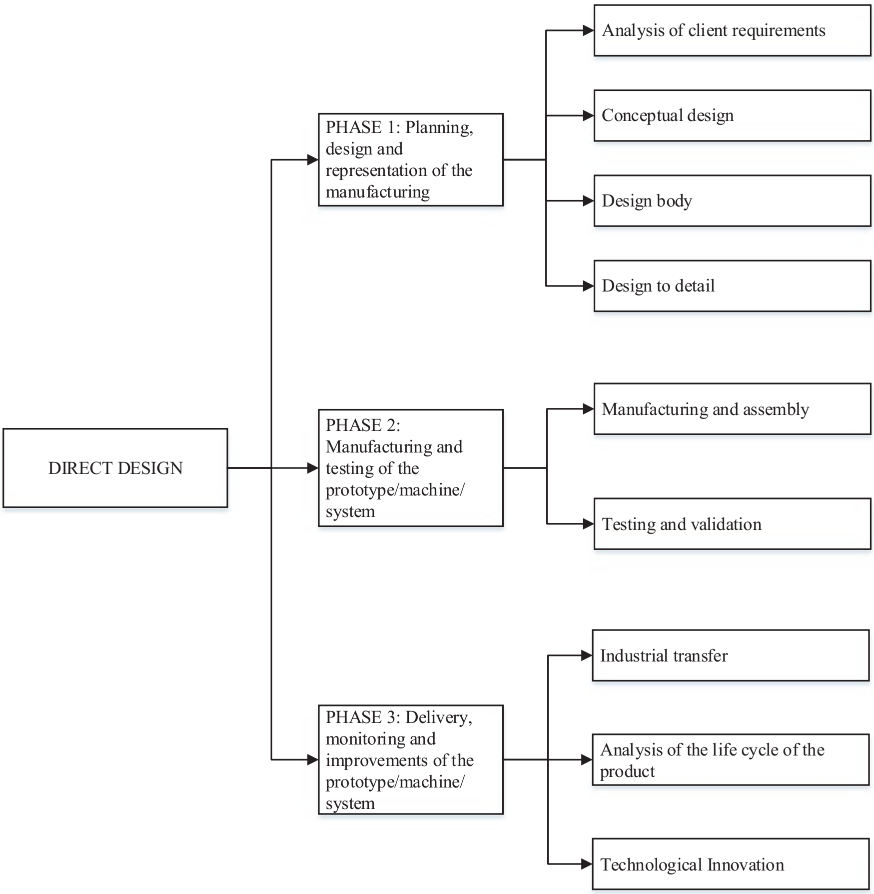

Fig. 7.2 Conceptual map of the direct design process

elements, and project development, provides the student with systematic guides about the design process, the connection between phases, and the importance of constant communication with customers. Figure 7.2 shows the conceptual map of the direct design, where the process is systematized in three parts and nine phases.

Procedures for the Systematic Measurement of Parts and Components

One of the applications that reverse engineering has, both in engineering education and in the industrial sector, is in the teaching of dimensional metrology oriented to the systematic measurement of parts and components. Traditionally, the teaching and learning of this discipline are focused more on the definitions, concepts, and good practices of measurement than on the development of projects that involve scientific measurements. Reverse engineering, through its programs and procedures, can help teachers and students to develop projects where measurements have to be systematic and reliable. This is achieved through the use of regulations and statistical processes, as well as the use of procedures that can be applied from the moment in which the piece or component is observed for the first time, until a statistical indicator or a logical review of the entire process validates the reliability of the obtained dimensional information. In the works presented by Jiménez et al. (2012, 2016), five procedures are proposed to systematically measure parts and components from a reverse engineering perspective:

1. From the preliminary analysis to the generation of primitives
2. From the selection of measuring devices to the verification process of calibration of the instruments
3. Measurement operation
4. From the analysis of the data to the representation of the information
5. Validation of the information

The first procedure is aimed at the systematic study of the piece to be measured and demand the students to make an investigation about the context of operation of the piece before measuring and that they get preliminary information under observation of the state and conditions of the object of reference. Subsequently, a map of linear, flat, and spatial primitives must be generated, with the aim of locating parameters that can be measured directly and indirectly. The study of the origin of the piece and the parameters of the primitives allows to select roughly the measuring devices that should be used. This procedure ends with the development of a technical report and the localization of the norms derived from the investigation of the context.

The second procedure is related to the analysis and selection of measuring equipment. The proper selection of the instrument, taking into account the parameters of the primitives, is an essential task that students must perform. Subsequently, it must be verified that the measuring devices are functional and that they are correctly calibrated. In this procedure, all the information available on the instrument and the procedure to verify its calibration and the associated norm are required. It is required to prepare a report on the results obtained from the selection, analysis, and verification of the calibration of the measurement instrument.

The third procedure is related to the conditions and the operation of measuring. This procedure requires the use and mastery of norms, both for conditioning the measurement laboratory and for determining the number of measurements that must be made to each parameter of the primitives according to the selected statistical process. It is necessary that students and teachers are capable to apply good measurement practices and safeguard the information obtained in databases. The preparation of a report of activities and results of the application of this procedure is required.

The fourth procedure is related to the handling of measurement information and the calculation of statistics. With the help of a spreadsheet or computational package, the measures of central tendency, dispersion measures, or correlations of the measurements must be obtained for each parameterized primitive, as required for the selected statistical process. This procedure is important since the information processed is the one used for the applications. The students must make a report of the activities and the results obtained.

The fifth procedure refers to validate the information in order to determine the reliability of the measurement. This process can be done by selecting an appropriate statistic or by reviewing each step of the four previous procedures. In the systematic measurements, it is necessary to have reliability criteria. Finally, a global report of the entire measurement process is made.

It must be mentioned that the procedures described above have a series of steps associated, which can be consulted in Jiménez et al. (2012). In order to be able to measure systematically a reference object, it is necessary that the references, objectives, and formalization of the reverse engineering problem be established, since the procedures described above represent analytical, synthetic, and equivalence programs or procedures. Some of the advantages provided by the procedures developed by Jiménez et al. (2012) are described as follows:

1. Students perform a visual and contextual analysis of the reference object with the purpose of obtaining a map of primitives that allow recognizing the primary and secondary parameters that must be measured.
2. They learn the importance of using norms in every measurement project.
3. Develop skills for good measurement practices.
4. Understand the importance of evaluating the reliability of measurements and statistical processes.

Finally, the procedures can be used to carry out advanced measurements, such as in coordinate measuring machines.

Procedures for the Documentation of Technology on the Basis of Direct Design and Reverse Engineering

One of the activities within the process of reverse engineering and direct design is the documentation of the designs or the models of the product. The manufacturing plans are generated through the entire design process or the results of an application of the procedures of metrology and procedures for the characterization of materials and manufacturing operations. Manufacturing drawings are specialized documents that combine geometric and non-geometric information of parts and components for a specific purpose.

The manufacturing plans represent perhaps the most important documents of the design process, since they include the systematized ideas of the designer and the geometric and manufacturing information of the parts and products. The manufacturing plans represent, on the one hand, the documentation of the technologies (of products) and, on the other hand, the design in terms of manufacturing. The manufacturing plan can be considered as one of the representations of the design whose purpose is to make the idea conceived, analyzed, and tested intellectually come true. Therefore, manufacturing plans are perhaps the most specialized representation of the design process; for its development, the highest considerations of design combined with considerations of manufacture are required, since there can be no design without manufacturing considerations.

Due to the importance that the manufacturing plans have within the design process, the duplication of parts and components, it is necessary, that engineering students domain the technical drawing and regulations, as well as the procedures that each company has for the documentation of their technologies.

The manufacturing plans represent in engineering the design of a product, machine, or device in terms of manufacturing and, consequently, must be created in a systematic way, that is, following a definition or a set of principles. There is no single definition of manufacturing drawings, since it is common to identify them as technical drawings. A formal definition of manufacturing plan is the one proposed by Jiménez et al. (2016):

> *A manufacturing plan is a physical or digital schematic representation of the design of a part or a set of parts that can be interrelated, in terms of manufacturing. Said representation contains geometric and non-geometric information of the parts and components, in addition, it must comply with the following considerations*:

1. Geometric and non-geometric information (manufacturing, costs, etc.) must be clear and as explicit as possible.
2. The information must be objective (essentiality, degree of importance of the information, etc.).
3. The information must be complete, finite, and well-defined.
4. The information must be regulated.
5. The information must be free of vagueness and ambiguity.

The definition described previously, along with its considerations, is associated with design schemes that are developed in the design phase in detail, since the geometric and dimensional information that is described is used for the manufacture of the components. However, to the extent that each consideration is not taken into account, other relevant information that configures the technology's documentation is generated. It is important to mention that the objectivity of a plane is required in the sense that the essential information must be the same regardless of the observer or interpreter. The information described in the manufacturing plans has two large information generating families associated:

1. Geometric and dimensional information
2. Manufacturing information (manufacturing)

The first family integrates geometric information such as arcs, lines, squares, circles, cones, parallelepipeds, etc. and dimensional information (units of measurement). The second family integrates information related to materials and manufacturing (manufacturing processes in general). It is important and necessary for engineering students to start with a formal definition of manufacturing plans equivalent to the common definition of drawings related to technical drawing, and especially that they have the ability to understand the enormous importance that the drawings in engineering and design have. The basis of the manufacturing drawings is the technical drawing, but it is not all, since it is necessary to incorporate manufacturing information and above all regulations, and the considerations of the definition must be fulfilled.

Below is a practical guide that can be used to help engineering students to develop the documentation of the designs:

1. Develop diagrams or sketches of the design idea or product either on paper or in computer systems.
2. Develop diagrams or sketches using more complete and representative information of designs, graphic forms, and materials of the product.
3. Develop all the calculations, representations, processes, and simulations necessary to verify if the proposed conceptual design should be taken into account or not, and raise spreadsheets of variables and selection of materials.
4. Incorporate all the necessary details to complete the missing design; introduce drawing norms, materials, and processes; and formally develop the necessary for the manufacture of the prototype.
5. Use the fabrication drawings to manufacture and assemble (if it's necessary) a prototype.
6. Adjust the geometric and non-geometric information of the manufacturing plans if necessary due to manufacturing or design considerations.
7. Carry out the tests, validations, verifications, and calibrations to the prototype and readjust the information generated in the plans to transform the prototype into a machine or part transferable to the industry.
8. Develop the plans of assembly, operation (in case of a machine), and maintenance (if it is a machine).
9. Develop a technical report of the transfer that includes all the final plans.
10. Perform a periodic check of the part or machine transferred to collect information that allows correcting errors or considerations not foreseen in the design and make improvements to the manufacturing, assembly, and maintenance plans.
11. Conduct research about innovations in the product market and propose changes or deep improvements. New plans must be generated.

To classify the manufacturing plans, it is necessary to consider three moments during the development of the direct design process:

1. Time 1: Creation of the product idea
2. Time 2: Formalization of the product idea
3. Time 3: Radical changes of the product

The phases of the design process proposed by Jiménez et al. (2013a) are used to generate all the documentation of a technology based on geometric and manufacturing information. Table 7.1 shows a classification of the types of drawings and manufacturing plans that are generated in all phases of the design process.

Table 7.1 Manufacturing drawings during the design process

Time	Phases of the methodology	Type of manufacturing plane	Description	Product or semi-product
Time 1	Analysis of customer requirements	Primary representations of the idea	Ideas, extended ideas, search for proposals, freehand drawing, computational representations of the idea, and basic representations of the product	Sketches, written ideas, and non-formal representations
Time 2	Conceptual design	Representations of the idea of the first formalization	Mature ideas, modeling of solids, scaled prototypes, first calculations, limited sketches and materials	Semi-dimensional sketches and semi-formal representations
Time 2	Body of design	Representations of the second formalization	Calculation of materials, kinematic variables, dynamics, sizing, simulations, models in solids	Spreadsheets and semi-planes
Time 2	Design detail	Representations of the second formalization	Detail of piece, basic connections, formalization of sketches, and introduction of drawing and manufacturing norms, formalized plans	Formal manufacturing plans
Time 2	Fabrication and assembly	Representations of the prototype	Manufacture of parts and components according to the plans and assemblies according to the plans, development of the first formal prototype	Reconfigured plans
Time 2	Validation and tests	Representations of the prototype	Prototype tests, calibrations and definition of operational parameters	Final plans
Time 2	Technology transfer	Representations of the transferred machine	Installation plans, maintenance plans, and final plans	Final plans, maintenance plans, and/or assembly plans
Time 2	Life cycle analysis	Representations of technology update	Continuous improvement of the machine and small innovations	Improved plans
Time 3	Technologic innovation	Representations of the innovation	Major changes in the design of the machine, considerable improvements, or radical change of product	Plans with major changes

On the other hand, in relation to the process of reverse engineering, if the information is validated by the five procedures and is used for the generation of a duplicate, it is necessary to apply five more procedures:

1. From the interpretation of the validated information to the generation of geometric primitives: In this phase, the information obtained by the application of the five procedures of component measurement is transformed into basic geometric objects, called primitives. The set of primitives and their interrelations will form the basic technical drawing of the manufacturing plans.
2. Procedure for the characterization of materials and manufacturing processes: This procedure is applied to determine the material (s) of which the reference object is composed, and to infer the manufacturing processes thereof.
3. From geometric primitives and manufacturing information to the normalization of information in manufacturing plans: This procedure is used to transform geometric and generic manufacturing information from steps (1) and (2) into normalized manufacturing plans.
4. From the interpretation of the manufacturing drawings to the generation of the duplicate. This procedure is used to manufacture a duplicate, according to the geometric and non-geometric specifications described in the manufacturing drawings.
5. From the interpretation of the duplicate to the equivalence tests: This procedure is used to validate the duplicate, that is, to determine if the prototype is representative of the reference object.

Competences and Learning Based on Projects

From a socioformative approach, Tobón (2008) defines competences as complex performance processes with suitability in certain contexts, integrating knowledge, to carry out activities and/or solve problems with a sense of challenge, motivation, flexibility, creativity, comprehension, and entrepreneurship. This, with metacognitive processes, continuous improvement and ethical commitment, to contribute to personal development, the construction and reinforcement of the social tissue, the continuous search for sustainable economic-business development, and the care and protection of the environment and living species. Seen this way, competences become an educational effort for the development of knowledge, skills, attitudes, and values that give the person an integral formation that considers all human dimensions.

In this sense, the La Salle University Northwest (located in Obregón City, Sonora, México), since its beginnings, considers in its mission the integral formation of the students and, in order to promote a pertinent formation to the new contexts, adds to its socio-constructivist curricular model the competency approach in 2011. This University *defines them as the interdependent set of knowledge, skills, attitudes and values that the student integrates with the purpose of solving problems in their per-*

sonal and professional field for social transformation. This definition of competences is in accordance with their socio-constructivist curricular model, since they imply the capacity to participate and act in a tight manner, that is, according to expected results of learning, defined as abilities. They are also linked to activities that are socially and individually relevant and they involve too the mobilization of a set of knowledge and psychosocial resources of a diverse nature. What competences add to their curricular model is potential to attribute meaning to school learning (Navarro et al. 2013).

At the didactic level, by basing the use of strategies focused on how students learn, active methodologies such as problem-based learning (PBL) and project-based learning (PrBL) are privileged. Both, located in the teaching methods oriented to the discussion and collaborative work, encourage the use of comprehensive long-term memory, the development of thought and motivation, as well as the use and transfer of knowledge, which allows its deep consolidation and learning fixation (Fernández 2005), fundamental activities for socio-constructivist learning based on competences. To select these active teaching methods as teaching strategies for industrial design and mechatronics engineering, the five necessary variables presented below were considered (Fernández 2005) in relation to the support they give to the development of professional competences. Table 7.2 shows the variables to select teaching strategies that support the competences.

Both are based on constructivism, mainly on three basic principles: the understanding that problems arise through interaction with the environment, the cognitive conflict when facing the problematic situation, and the obtaining of the knowledge through social processes and of the evaluation of the different individual interpretations of the same phenomenon (Navarro et al. 2013).

Project-based learning is a didactic strategy to form competences from a socio-formative approach, for an active and integral learning. It brings a specific work reality to the academic environment and encourages active learning. What is sought

Table 7.2 Variables to select the didactic strategies that support the competences

Selection criteria	PBL	PrBL	Support for the specific and/or generic competences of Ulsa Norwest
1. Levels of cognitive goals	Superior	Superior	Intellectual and professional development
2. Ability to promote autonomous and continued work	Raised	Raised	Learn to learn Planning of the learning process Formative evaluation Identification and resolution of problems
3. Degree of control exercised by the student	Raised	Raised	Increase of responsibility and autonomy, decision-making; capacity for analysis and synthesis
4. Number of students that can cover	Medium	Medium	Reduced groups
5. Number of hours of group preparation and for corrections	Large	Large	Promotion of social skills and help relationship Increase in the degree of commitment and responsibility

is the development of superior cognitive processes with the application and integration of knowledge, through the elaboration of a plan with defined strategies, to give a solution to a question and not only to fulfill curricular objectives. The students analyze the problem, propose and apply a solution, and evaluate this proposition. At the end, they usually produce a specific "object" (prototype, model, and intervention plan), a written report, or an oral presentation (Fernández 2005).

Characteristics of the project-based learning model (Navarro et al. 2013) have been identified as being centered and directed by students with problematic real-world content that is meaningful to them and promotes the elaboration of products by investigative processes. These are as follows: promotes the interrelation between academics, reality, and work skills; generates feedback and evaluation by experts as well as reflection and self-evaluation by the student; helps an evaluation based on evidence of learning; and develops generic competencies as specific objectives related to the standards of the educational curriculum for the twenty-first century. These characteristics are related to the ability to formulate and manage projects, such as knowledge about the area of study and the profession, capacities of abstraction, analysis, synthesis, criticism and self-criticism, decision-making, organization, identifying. As well as formulate and solving problems of communication and interpersonal, investigative and information processing skills, use of tics, ethical commitment, teamwork skills multidisciplinary, application of knowledge, autonomous work and in new situations, creativity and commitment to quality. According to Barrio et al. (2010), in each of the PBL stages, the teacher and students perform specific activities (see Fig. 7.3).

On the other hand, the selection of the project to be developed is key to achieving the objectives set. This must be real, according to the context of application of the subject, challenger for the students, feasible within the stipulated period, and

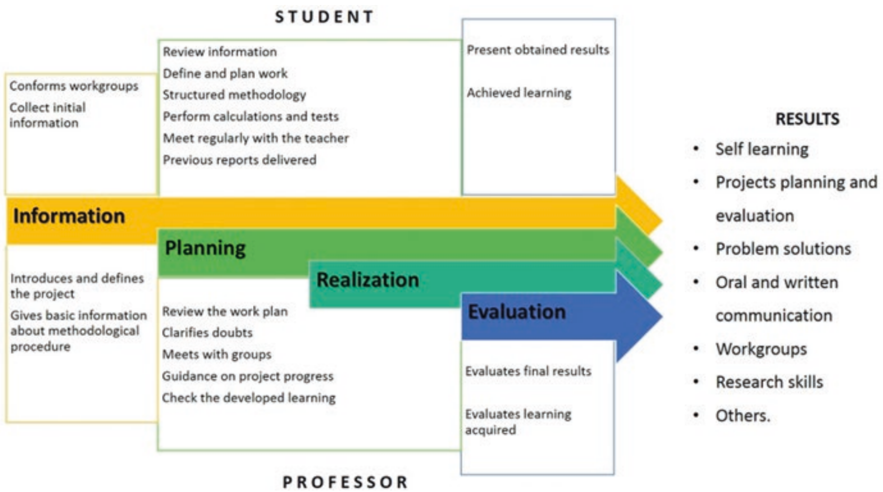

Fig. 7.3 Tasks of the teacher and the students in the project-based learning (Barrio et al. 2010)

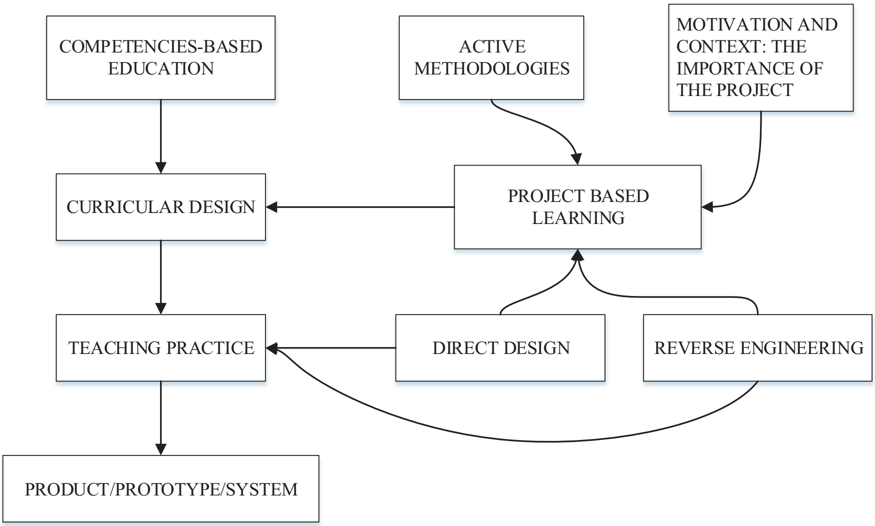

Fig. 7.4 Map of interrelations between concepts

correctly administered. It must be such that it is possible that at least one unit of competence described in the curricular plan can be associated with the project. One of the fundamental characteristics of project-based learning (PBL) is that it affects the curricular plan and class planning. For this reason, it is necessary for the teacher to review, analyze, and plan efficiently the project so that it can be incorporated into the planning of classes in terms of tasks and activities. Since the PBL incorporates a variety of models or methods for the development of the project, reverse engineering and the direct design method are incorporated in two ways: as part of the planning of classes and in the execution of the project. Figure 7.4 shows a map of relations between the concepts of competency-based education, curricular plan, PBL, reverse engineering, direct design, active methodologies, and project motivation.

Study Cases

In this section, we present the description of some study cases and the methods and procedures proposed in this work. The first study case is an automotive component, to which four reverse engineering research programs were applied. For the development of this project, the active PBL method was used. According to Farhana et al. (2017), when the PBL approach was implemented in the classroom, students bought opportunities to get involved in a real-world problem. Students face problem-solving and decision-making with great responsibility. This method has four phases: (1) information, (2) planning, (3) realization, and (4) evaluation. One of the characteristics by which this method is selected is because it adapts better and naturally to engineering education.

Below is a summary of the reverse engineering project associated with the part shown in Fig. 7.5.

The objectives in this project were the following:

1. Study the cover of an automotive component.
2. Make models of the products without the actual manufacture of the piece.

The programs selected for the study of the component were the following:

1. Digitalization of the component (cover)
2. Solid modeling of the component
3. Manufacturing modeling
4. Sustainability analysis of component manufacturing

The process of reverse engineering was carried out using the five procedures related to the measurement of parts and components. The programs were applied sequentially. Figures 7.6 and 7.7 show the digitization process performed on the piece under study by means of a coordinate measuring machine and the modeling of solids developed in the SolidWorks software.

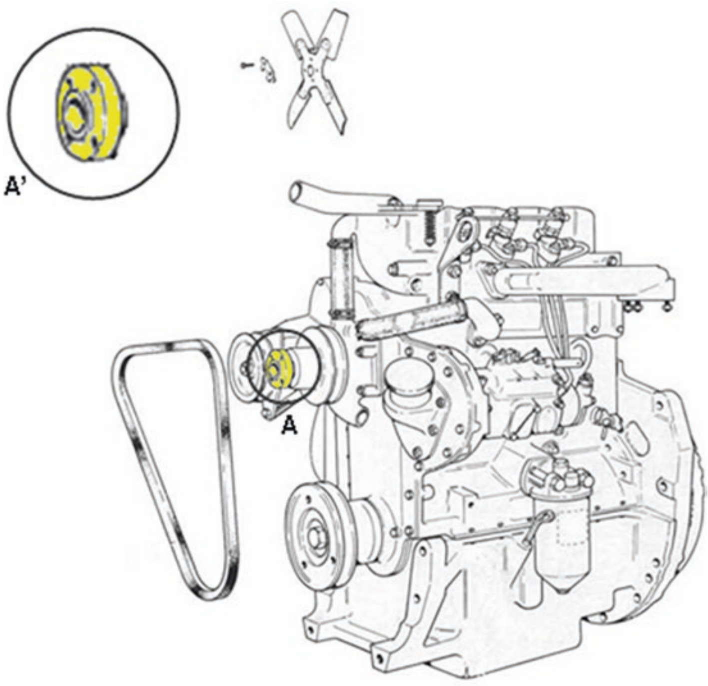

Fig. 7.5 Reference object

Fig. 7.6 Process of digitizing the component

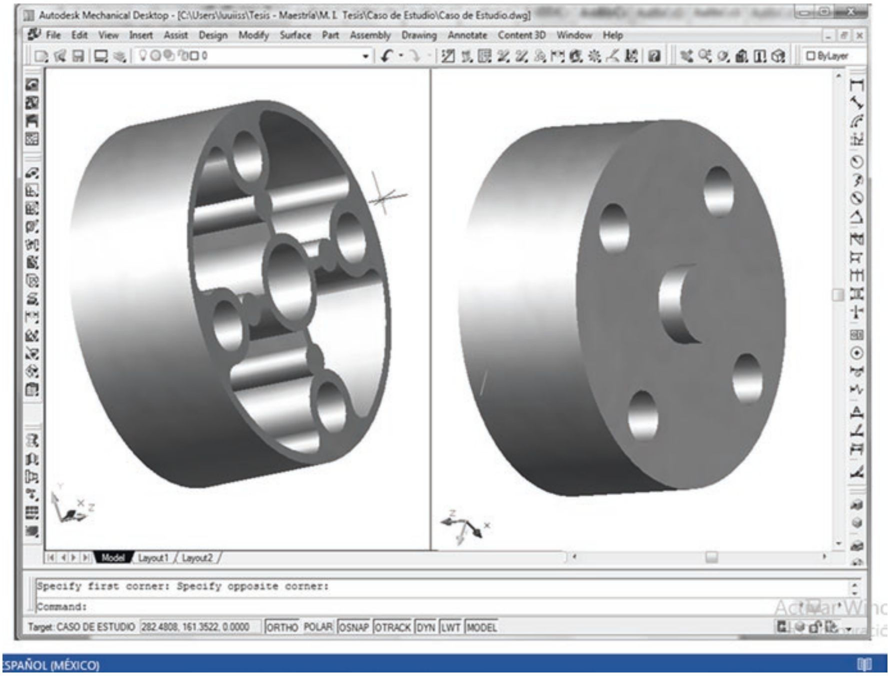

Fig. 7.7 Modeling of solids of the component

Figure 7.8 shows the simulation of the manufacturing process carried out in Mastercam, and Table 7.3 describes the results of a sustainability analysis enhanced to the piece with the geometric information of program 2 and the materials of program 3.

Other projects developed with the procedures proposed in this paper are summarized below:

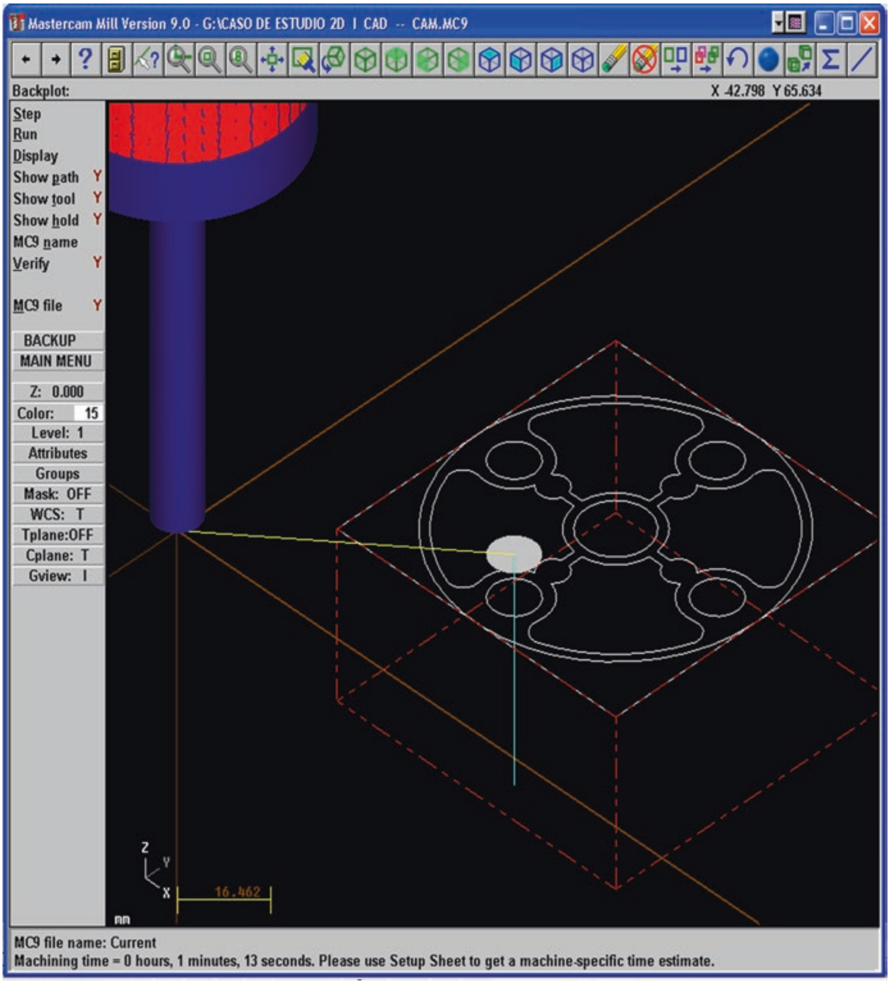

Fig. 7.8 Manufacturing simulation

The students of the Universidad La Salle Noroeste developed a machine for weighing and dosing corn chips for an agro-industrial company. In this project, they used the steps of direct design. Figure 7.9 shows the device operated in the benefited company.

Finally, the students and professors of the La Salle University developed an improvement in the manufacture of rustic furniture. In this project, the direct design method was used to study the product and to implement an improvement to a workshop for the systematic manufacture of furniture known as a stool. The company is a cooperative that was formed with members of the Guarijia ethnic group, located in southern Sonora, Mexico, and its goal was to increase the production of their product due to market demand. Figure 7.10 shows the furniture and the workshop restructured.

Table 7.3 Sustainability report derived from the evaluation of SolidWorks sustainability

Sustainability report			
Piece:	Top		
Material 1		Material 2	
Stainless steel 316		Ductile iron	
Fabrication process:	Milling	Fabrication process:	Sand molding
Weight:	301.33 g	Weight:	267.43G
Manufacturing and use:	North America	Manufacturing and use:	North America
Built to last:	1 year	Built to last:	1 year
Use during:	1 year	Use during:	1 year
Electrical consumption:	0.629 kWh/lbs	Electrical consumption:	0.621 kWh/lbs
Recycling content:	18%	Recycling content:	84%
Transport:	2600 km	Transport:	2600 km
At the end of useful life:		At the end of useful life:	
Recycling:	33%	Recycling:	33%
Incinerated:	13%	Incinerated:	13%
Dump:	54%	Dump:	54%
Environmental impact		Environmental impact	
Carbon footprint:	1.9 kg CO_2e	Carbon footprint:	0.675 kg CO_2e
Total energy consumed:	21 MJ	Total energy consumed:	6.1 MJ
Acidification of water:	8.1E-3 kg SO_2e	Acidification of water:	1.7 E-3 kg SO_2e
Eutrophication of water:	6.5E-3 kg PO_4e	Eutrophication of water:	4.7 E-3 kg PO_4e

Fig. 7.9 Device for filling of corn tortilla chips

Fig. 7.10 Stool and the improved production workshop

Results and Discussion

The procedures related to the measurement of parts and components, the method of reverse engineering and the direct design process proposed by Jiménez et al. (2013a), are applied in various subjects of the careers of engineering in industrial design, mechatronics, and industrial at the Universidad La Salle Noroeste and at the Universities that make up the ALFA NETWORK, located in Cd. Obregón, Sonora, México. To improve education in engineering, in Mexico it has been migrating from traditional teaching (teacher-centered) to competency-based teaching (student-centered), so that teachers in the engineering areas have received training in the competency-based approach and the use of active methodologies to improve learning. For this reason, it has been possible to use the PBL and the procedures derived from reverse and direct engineering in various projects of companies, and through this process, students can contextualize the theories in real applications and put their skills and competences into practice in the solution of real problems.

The methods and procedures proposed in this chapter are useful and practical in the sense that they can be used in various fields and areas of knowledge, such as the study of manufacturing processes, industrial design, metrology, and materials analysis, duplication of parts, industrial maintenance, sustainability analysis, and pedagogy, among others. Therefore, it is necessary for engineering students to learn the different methodologies that exist to develop projects using reverse engineering and direct engineering, under the application of methodologies focused on students, such as the cases of project-based learning and the problem-based learning.

It is worth mentioning that although the procedures described in this chapter are applied through many steps (Jiménez et al. 2012, 2013b), in the end these help the engineering students to understand the practical complexity of a real design problem or a reverse engineering problem. The development of projects of the companies introduced in the academic projects increases the motivation and commitment on the part of the participating students and professors, since the real considerations of these projects involve the preparation of a planning and a correct administration of activities and encourage students to systematically implement the skills learned in the classes.

To evaluate the performance of students, various tools or methods are used, such as rubrics, development of reports, exams, and visits to companies, among others. However, the input that has more value is the product in use and its documentation, as long as the commitment with the company to deliver a prototype or machine has been made.

Finally, in relation to the definitions on reverse engineering and manufacturing plans described in this paper, these were proposed to guide students toward a better systematization of engineering processes and for the documentation of technology. Although the intention with the definition of reverse engineering was its application in the didactic, it is also possible to extend the applications to other fields of study because, in general, reverse engineering is a general analogy of the scientific method, in the sense that they are used for research and they are systematic.

Conclusions

In this chapter, some procedures and programs derived from reverse engineering and direct design have been presented, which are used to aid learning in engineering education. The main conclusions that derive from this work are summarized in the following points: To promote the active training of current engineers, it is necessary to propose technical and pedagogical procedures that improve their skills and promote the formation of generic and specific competences. The technical procedures described in this chapter, related to the reverse engineering process and the design process, combined with the PBL, provide engineering students with valuable tools to perform scientific measurements and document the development of prototypes and, at the same time, they promote a progress from the basic levels to the upper levels of Bloom's taxonomy (O'Brien and Abulencia 2010). Active methodologies are necessary in engineering education, since they promote autonomous learning, teamwork, and research in students. In addition, the PBL is naturally attached to the development of engineering projects, which facilitates the guidance of students, improve their learning, and design better assessment methods. Technical procedures related to the measurement of parts and components require students to order, systematize, and use standards and statistical tools in the dimensional and geometric study of pieces to be measured. The direct design method proposed by Jiménez et al. (2013a) helps students to know and actively practice the relationships between designers and clients. It allows them to know the technical and financial documentation of a project, as well as the relationships between each phase of the design process. The definition of reverse engineering proposed by Jiménez et al. (2016) generalizes the applications, since this method of engineering is not necessarily applied to parts, components, or machines, but it may cover the study of a system in general. The phases of reverse engineering and the systematization of the process in 11 steps allow a better and more complete study of the reference object and its representative model. The technical documentation of technology is a crucial task in companies and universities. Considerations about the manufacturing plans and the proposed classification help students to generate and document the geometric and non-geometric information of parts, components, and machines.

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Chapter 8
Teaching Safety, Health, and Environment in Engineering Programs for Millennials: Ethics Is the Basis

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Engineers Behaving Ethically

- Engineers have an ethical responsibility to protect workers and the public (safety, health, and environment).
- They will have to act with integrity (values-congruent).
- Ethics can be taught to diverse groups.
- Educators and mentors must teach and model ethical behavior in personal and professional life (values-congruent).
- A good recipe for success in undergraduate programs combines coursework in philosophy and case study discussions to help students develop their personal moral code that aligns with international engineering moral codes.

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Background and Purpose

Visionary Model for Addition to Engineering Curricula

Engineers design and build systems and structures for the good of society. Often the system is so complex that only the engineering team or sets of teams can conceive the many possible safety, health, and environmental (SHE) risks inherent in the construction, operation, maintenance, and eventual termination of the system. An SHE expert outside of the engineering teams can give consultation, but never fully understand the system as intricately as the teams do. Therefore, engineers must have some education in SHE risks to elucidate their understanding and application of risk control principles. The application of SHE risk management is essential not only for altruistic avoidance of human and environmental harm but also for realization of profit for an organization.

Empirical Evidence for Safety, Health, and Environment Ethics into Culture, and Culture into Profit

Some well-known organizations have turned around their safety culture from being fear and rule based to being a company where safety is the cultural norm. Consider the Aluminum Company of American (Alcoa). Alcoa's president, Paul O'Neill, was US Secretary of the Treasury under George W. Bush and, earlier, the Chief Executive Officer (CEO) at Alcoa. As O'Rourke, O'Neill's vice president, relates, Alcoa was in the red and headed downward when O'Neill took over. O'Rourke says:

> Paul made safety a true value at Alcoa. He spoke safety at every meeting. He drove for improvements in reporting, in sharing safety risks across the corporation, and in eliminating those risks. His safety focus, from the top of the corporation, resulted in incident rates falling every year through his 13-year tenure until Alcoa became the safest manufacturing corporation. More importantly, he set the culture so that the incident rate would continue to fall long after he left the corporation.
>
> When I was asked to become the first president of Alcoa's Russian operation, I reviewed the situation and found that everything needed to be improved: pricing, compensation, relationships, systems, procedures, financial processes, housekeeping, product quality—everything. Where do you start? I decided to start with safety.
>
> These two huge Russian facilities averaged five deaths per year for 50 years, their incident rates were 10 times higher than Alcoa's, none of the 16,000 employees wore protective equipment, there were no safety meetings, no safety training. By focusing on safety, putting employees in protective equipment, training the employees on safety, auditing the health and safety practices, focusing on housekeeping and making safety a true value, positive change happened. In the first full calendar year that Alcoa owned these Russian facilities, there were no fatalities, and today they have gone seven years without a fatality. These Russian facilities have incident rates lower than Alcoa's exemplary corporate rate. And, by driving improvements in safety, we demonstrated that improvements are possible everywhere. (Agle et al. 2016)

Look at what others say about Alcoa's values turned into profit. At the beginning of his tenure, O'Neill encountered significant resistance from the Board of Directors due to his stance on prioritizing worker safety. By improving Alcoa's safety record, the company's market value increased from $3 billion in 1986 to $27.53 billion in 2000, while net income increased from $200 million to $1.484 billion (Duhigg 2012).

Engineering Safety, Health, and Environment Curriculum

Safety, health, and environmental risk recognition and control are critical curricular topics for engineering education according to ABET (2017b) as is ethics. However, engineering professional societies such as the American Society for Engineering Education (ASEE) do not have a clear vision of what should be taught at the undergraduate level (Winn and Slagley 2016). Accreditation criteria for undergraduate engineering programs include SHE as well as ethics. The National Society of Professional Engineers' (NSPE) code of ethics, first fundamental canon, states that professional engineers must "hold paramount the safety, health, and welfare of the public" (National Society of Professional Engineers 2007).

The World Federation of Engineers' code of ethics includes provisions for SHE, as does Engineers Ireland (Engineers Ireland 2018; WFEO 2018). But, what are the underlying ethical codes the professional societies appeal to? There is an unstated assumption underlying the ethics codes that the society from which the practicing engineers come and the society within which they practice share a common ethical code or standard of moral behavior. It is sufficiently problematic to practice engineering ethically within one's own society. Even when operating with the same ethical standards as the home society, there may be pressure from various parties to act against those same standards. Given the multinational milieu of business, nongovernmental and government organizations, few engineers trained at any institute of higher education across the globe will spend their careers practicing within their home society. Further, the variation in underlying moral codes across the world's societies has given rise to the expediency of moral relativism. Rather than argue for a universal moral truth or wrestling with applying a moral truth to a specific situation, many simply dismiss the situation as a cultural difference.

Luegenbiehl and Clancy (2017) propose that engineers should not compromise moral obligations, but should defer to local culture for any nonmoral issues (Luegenbiehl and Clancy 2017). They claim that their approach does not equate to moral relativism as they appeal to reason and the "nature of engineering." They suggest that all engineers would arrive via reason at the same ethical principles (such as to do no harm to the general public) due to the nature of their training as engineers. Then they will be equipped to select a correct alternative for a decision concerning ethical principles and defer correctly to the local cultural values for "nonmoral" decisions.

The problem again arises in assuming that there are already underlying common morals across societies. Some assume that since the United Nations adopted in general assembly and published the Universal Declaration of Human Rights in 1948, all cultures naturally accede and adopt these. Such is not the case. Some cultures would openly reject some of the articles, and some would agree in assembly but refuse to honor articles in practice. For instance, the right to "freedom of thought, conscience, and religion…includes freedom to change his religion or belief…" (United Nations 1948) is at odds with written laws and practices in several member nations throughout the world. Whereas human reason can be cited as the source for the universal human rights, this paradox demonstrates that what are considered fundamental ethical norms by many peoples across many cultures may be completely rejected by others.

It may be acceptable to appeal to an engineer's fundamental ethics if they share a cultural heritage of ethical norms congruent with the universal human rights. If the engineer does not share these cultural ethical norms, then assuming they will use their reason to arrive at the universal rights is false.

Since engineers perform duties for the good of the society, and their poor decisions can also harm many people in the society, it is incumbent upon those who educate and inspire young engineers to train them in ethics congruent with the national and international engineering ethical codes. The question becomes how to approach effective ethical development, and the answer depends on the student audience.

Student Audience

As this text addresses college curriculum for engineers to work in a global context, this chapter will focus on younger engineers primarily from the millennial generation. Most current young engineers and engineering students have grown up in the digital age and have been labeled "millennials" by those studying society. Several researchers have described aspects of the millennial generation and contrasted them to older generations, from which older practicing engineers come. Older engineers are often set in their ways and practices. They naturally have more work experience. Many are less comfortable with the digital age and social media. While they tend to be accepting and encouraging of computer-aided engineering tasks, they may not be executing the tasks as much as managing younger team members who perform the tasks. Older engineers have developed a network of professional and personal relationships as they have built their reputations over the years. As they have matured, they often have settled into and adopted the ethical norms of their society. Developing nations have sent their own students to colleges in more developed countries. This can result in differences between the ethics of the home society and the school's society when the trained engineer returns home. The modern effort to encourage high-quality engineering education across the globe allows students to be educated within the ethical culture wherein they will practice. However, multinational organizations increasingly hire engineers to work in societies outside their home area. This situation results in a stronger need for effective ethical curriculum aligned with international engineering ethical codes.

There is no doubt that humanitarian concerns come first in any discussion about the role of ethics in undergraduate engineering training. We recall that every engineering code of ethics, regardless of discipline, begins with the responsibility of the professional engineer to maintain the health and welfare of the individual and the society. It turns out that humanitarian and financial stability can go hand in hand in a values-congruent culture purposely created, starting with a solid understanding of ethics and morality during the undergraduate years.

What About Millennials?

Rather than being distracted by whether praising or bashing millennials is in the popular press, the clear majority of sociological and organizational behavioral research available in the last decade suggests that the millennial generation, that is, young people born between 1982 and 2002, represent a significant group which is *socially unique*.

> The first of the Millennials started their working careers in about 2002, and they have entered middle management in about 2012. The Millennials represent a twenty-year span of people born after Generation X. They have solidly entered the workforce after college, about 2002–2004, and now ten to twelve years later, they are entering leadership slots. In terms of size, the Millennial generation is big, indeed, very big. In fact, it is the biggest generation to come along in fifty years and the reason seems to be because the Baby Boomer generation preceding it delayed childbearing for a longer period than in earlier generations. The Baby Boomer parent was tending to be in mid-career and having children for the first time in their 30s and 40s. (Winn et al. 2015)

To summarize the recent literature,

- Millennials are more altruistic and less bound by tradition than their parents.
- Millennials in engineering are more likely to have a college degree than their boss.
- Millennials are more likely to have studied organizational behavior than rely solely on rules and enforcement.
- Millennials actually want to talk about ethics and morality.

Millennials have been described as altruistic, very comfortable with digital media and virtual social interactions, and practical moral relativists. Moral relativism can be described as letting the individual decide the moral good, without any universal principles of good. In effect, this becomes indifference to moral truth. The natural end of someone espousing the lack of universal moral good for others is eventually they reject moral good for themselves—while they may outwardly subscribe to a set of values, they cannot justify demanding those values of others or even themselves.

Compounding the need for ethics education and training is a generation of undergraduate students who, while purporting altruism, do not apparently hold a clear sense of the need to act values-congruent. Values-congruent behavior simply means that the behavior of the engineer is aligned with the values he or she espouses. However, cultural differences in decisions for action or inaction can result in serious public harm when moral truths are ignored, particularly in SHE operations. Therefore, we propose the inclusion of not only ethics and SHE risk but also philosophical training within the engineering curriculum.

Approach

We have experienced and worked in the preparation of engineers under both public university and US military college models. Experience over decades across generations of American and international students has suggested innovations which have been implemented with some success. One new challenge is the characteristics of the current generation of youth. As stated previously, the millennials have come of age in the digital era. The constant flow of information and ideas at their fingertips tends to encourage questioning and sometimes rejecting societal traditions. Some of these traditions are de facto enumerations of underlying moral codes. At US military colleges, where all students have some engineering education, all engineers must also take required philosophy courses. The military colleges go further to inculcate a strict moral code throughout the students' experience. For instance, the honor codes of the US Military Academy (West Point, New York), US Air Force Academy (Colorado Springs, Colorado), and US Naval Academy (Annapolis, Maryland) all state similar artifactual standards, "We will not lie, cheat, or steal, or tolerate among us those who do." Students who violate these standards, even in their private lives, may be disciplined or even expelled from the institutions. The justification is often that military officers make decisions that put lives at risk. They must have integrity—values-congruent behavior. Further, this artifactual code demanding integrity is reinforced via a 4-year experience of thorough immersion within the academies' cultures full time—24 hours per day. The cultural immersion allows for education and experiential learning by applying the moral principles and observing the outcomes. Students progress through ranks with increasing levels of responsibility and authority. They first experience following their leaders and living with the decisions of senior students. They earn more responsibility and then wrestle with actual moral issues, make decisions, and enjoy the ramifications of those decisions in their own lives as well as the lives of their subordinates. Finally, the military colleges apply extra stress through physical and mental demands, sleep deprivation, limited time to complete tasks, and holding students accountable for the actions of others. The purpose of the rigorous educational *culture* is to "build leaders of character."

Dr. Edgar Schein is credited with popularizing the term "culture" as it applies to behaviors and beliefs allowing an organization to confront problems (Schein and Schien 2004). There is no textbook master plan for creating a culture—a culture just emerges as a problem-solving tool. But Schein suggests that those beliefs and behaviors can be shared and taught. A culture is not some mysterious and unknowable thing.

One of the most important concepts identified by Schein was the notion of "authentic culture," which means that a group or organization must meet three criteria, no less, to be considered authentic and values-congruent. The group must provide visual, nonverbal consistency with its stated values. This can be in the form of a logotype such as the green cross used by many safety organizations. No words are necessary to understand that an organization promotes safety, at least visually through its artifactual expression of values.

Second, Schein says that a group must also express its stated values in the form of a mission statement, slogans, letterhead, or other forms of written expression. Those are Schein's espoused values and they are necessary for the group to identify itself as values-congruent, or authentic.

Third, and certainly most important, Schein says that a group must act publicly and openly in correspondence to its stated values. This he calls "values in action" for obvious reasons, but they must exist in the presence of espoused and artifactual values to consider the group authentic.

Because engineers often work in the public eye, and hence under public scrutiny, it is important to maintain close correspondence between what they do and what they say they should do. For instance, consider an engineering firm building a series of condominiums has a large sign in its conference room about how it values worker safety. If it allows a worker to be exposed to fall hazards such as in the image below (Fig. 8.1), there is an obvious disconnect between what it does and what it says it does. Workers—and the public—see this disconnect immediately, and dissatisfaction and mistrust quietly grow, first in dark corners of conversation near the water cooler, but later in a much more public way when the firm is disqualified for a bid because of negative media coverage of a fatal fall from that same building.

Therefore, essential curricular ingredients are artifacts of public expression of values, culture of acting values-congruent, and education in ethics to support the students' consideration of ethical decisions during realistic experiences and discussions.

We propose a method of classical philosophical instruction and discussion starting with Plato, then using a values-based construct such as Aristotle, followed by realistic role-playing or other experiential-based learning experiences to help students think through difficult SHE decisions and moral dilemmas. This will form a basis for an application course exploring artifactual and values-congruent behaviors to help students develop their personal moral code in light of established SHE and general engineering societies' codes of ethics.

Fig. 8.1 Worker with no fall protection and clear hazard of falling from this roof. (Image: Winn 2016)

Artifactual Values Example: The Honor Code

> As Aristotle asserts, there are five ways to reach the truth, among them practical wisdom. Further, he states that there is a kind of practical wisdom wherein the subject knows what to do in a situation, even in absence of using deliberation to arrive at the decision. (Ross 1925)

"We will not lie, steal, or cheat nor tolerate among us anyone who does." This phrase is memorized by the young basic cadets of the United States Air Force Academy and sworn before they are accepted by the cadet wing. It is inscribed on the honor wall and governs their lives for the next 4 years. Rumors are whispered in classes and while walking to lunch that Cadet X was found in an honor violation and is being expelled from the Academy. Worse yet, so is his friend, Cadet Y, for simply being aware of the act and failing to report it. Many cadets have mixed feelings about the honor code, but it does its job of establishing an environment in which lying, stealing, or cheating in any form is not tolerable. Despite the countless opportunities for violating it, cadets do abide by it for whatever the chief reason: respect or fear.

The origins of this honor code are found in the older institution, the United States Military Academy at West Point, New York. The philosophy behind this code is that as future military officers, high moral values are not simply desired, they are demanded. The academies train their officers by enforcing this code in the hopes that it will dictate their morals in their careers to come.

For some cadets, the honor code changed nothing in their moral life. They came from backgrounds in which those rules were already established and followed. But in mandatory honor discussions, some cadets admit that prior to being a cadet, lying, stealing, and cheating were the norm. As the academies pull from a wide pool of people, there are many cadets whose backgrounds gave them very different moral frameworks. It is here that the honor code proves most useful: it establishes for all the aspiring officers a common moral framework, something that they can all relate to despite their diversity.

Engineers, although not in the profession of arms, are also professionals in whom the public places trust. An ethical framework allows not only the engineers to properly make decisions but also for the public to trust them, just as the cadets trust each other. The million dollar question is, "What ethical framework?"

It is natural to want a simple black and white answer. This is right and that is wrong. That is what the honor code does. It tells cadets, to some extent, the rules that they should be following. However, in more intimate discussions about the honor code among their peers, cadets reveal their mixed and skeptical feelings. What if they knew or suspected that their good friend violated the honor code? According to the code, they are mandated to report them. Throughout basic training and continuing for the remainder of the 4 years, another code is inscribed in cadets' hearts: *wingmanship*. Never leave an Airman behind. It is not simply propaganda. Cadets learn very quickly that they cannot survive without the people to their right and left. Helping out a buddy means that when—not if—the time comes that you cannot keep up, your buddy will be there to take care of you. This lesson is most intensely learned in basic training but resounds throughout the rest of the time. It is arguably the most well-learned lesson. What happens if the honor code tells you to violate this cultural code?

In one semiprivate discussion on the honor code, the facilitator raised this very question. As it was a session of peers, everyone felt rather comfortable and the squadron commander answered what everyone was thinking. "I respect the honor code, but I don't think I could ever turn in my buddy." No one in the room contradicted that statement.

This dialogue introduces an important point: ethical frameworks are not completely clear and they are not an easy answer. They can contradict each other.

Knowing the right thing to do in a given situation can be difficult. Philosophers have been developing different theories and different frameworks to help moral dilemmas, but at the end of the day, the individual must make a decision. One hopes that it is at least an informed decision.

Ethics Education in the Curriculum

Part of the core curriculum for each of the three US military academies (West Point, Colorado Springs, and Annapolis) is an ethics class. This class is a survey of different philosophers, their theories, and an introduction into ethics. Many students enjoy the class, and many are surprised that there is not one simple answer. A reason why this is a mandatory requirement for graduation is because the institution recognizes that the act of developing officers requires this type of education. If there was an easy answer, then there would be no need for further education. This class exposes the more difficult task of the "gray area" and by going through different theories and frameworks arms the young officers with something more important: tools. The individual responsible for making a decision is not a robot. He should understand the gravity of the situation, what is at risk, and should have tools that enable him to properly analyze and make a decision—even without a clear right and wrong answer.

The same can be said for an engineer. There may be some clear choices where one side is obviously wrong—which is a moral temptation, not a dilemma. However, for the situations in which this is not the case, having a sound background in ethical frameworks will enable the engineer to make a good choice even when there is no best choice.

Part of the officership training the Air Force Academy executes through the Center for Character and Leadership Development (CCLD) focuses on character training. They give cadets a list of values and ask them in different sessions to reflect on these virtues and begin practicing them in their professional life. This type of training originates in the Greek philosopher Aristotle's approach in ethics. Aristotle supported character or value-based ethics. He believed that virtues are the proper mean between two extremes (the golden mean) and that practicing these virtues (forming habits) creates virtuous people. For example, the virtue of courage is the proper balance between the extremes of rashness and cowardice. Someone who creates the habit of being courageous becomes a courageous person. People who live the virtuous life will make the right decisions. Therefore, in Aristotelian ethics, the right approach for establishing an ethical framework is to focus on the individuals. If one can teach people the proper balance, and can encourage people to form good habits, then the virtuous people formed by this will be the source of proper behavior. Although the CCLD does not mention Aristotle and his philosophy, their approach is clearly Aristotelian.

Giving students a list of virtues might be helpful to begin a discussion and to set the tone. However, most people are not happy with simply accepting whatever is told to them. They naturally question why those virtues are important and what exactly they look like—as they rightly should. The core philosophy class offered at the Air Force Academy gives a survey of philosophers and ethical frameworks, attempting to give all cadets the foundation of ethics. Though not directly connected to the CCLD, it complements it well. It actually teaches Aristotle and his approach—the "why" behind value-based training.

The result of character-based ethics is the development of a virtuous person who can discern right from wrong. It does not mean that all situations will be clear; it simply means that the person will have the tools to make progress in moral dilemmas. One must admit that even with the above training, the individual may not agree with Aristotle and may believe in another ethical approach. For example, he may agree more with Kant's principle-based ethics in which one should discern the right principles and perform his duty, or he may agree with a consequential framework in which all that matters is the end result of the action. Teaching philosophy can be dangerous because there is not one promised end game. Perhaps this is why the CCLD does not directly teach character-based ethics and why it simply gives and defines the desired virtues. What is the alternative? Teachers can take a strict approach and tell students exactly the type of behavior and virtues that are expected to make good engineers. Some students may accept it and not question. More than likely, however, many students will not just accept it because it is taught in class. As engineers come from around the world and, therefore, many cultures, their different backgrounds will offer more opportunities for them to take different perspectives on the coursework, and perhaps more questions on the rationale behind the curriculum.

From Coursework to Application

A course in philosophy which covers the basic ethical frameworks gives students a solid background to apply ethics. It offers an opportunity for students to analyze moral dilemmas. Obviously, in the field, decisions will not necessarily be ethically crystal clear. Understanding the background of ethics ensures that students will be able to better analyze moral dilemmas and make good decisions. While classwork can never replace field work—being actually in the middle of an ambiguous situation and making a decision, case studies offer perhaps the closest alternative. In the book *Engineering Ethics: Real World Case Studies,* authors Starrett, Lara, and Bertha begin by giving a brief introduction into the field of ethics. The remainder of the book focuses on engineering case studies for the engineer to reflect on and analyze. They say, "If you thoroughly consider what you would do in the presented cases…we are confident your ethical problem-solving abilities will be significantly strengthened" (Starrett et al. 2017).

Plato, the founder of Western philosophy and "the Academy" of Ancient Greece, has influenced philosophy and academics in all corners of the world. In his works, he does not give clear answers to his questions but instead leads his readers through dialogues presenting different answers and opinions through his characters. Plato is not a moral relativist; he is actively seeking the truth and the good. There is clear falsehood and evil that can be recognized and that has bad consequences in the world. In *The Republic*, arguably the greatest of his works, he answers the question, “What is justice?” He builds an imaginary just city, answering what justice looks like in a city and in a soul. The question, “What is justice?” is the foundation of ethics. Plato believes that there is justice and that we can recognize it within certain contexts (Jowett 1871). A philosophy class that uses Plato as an introduction to ethics allows the students to wrestle with these questions and find contextual answers to ethics. It does not simply give easier answers and frameworks which may be unsatisfactory for discerning students but demands the students to seek truth and justice in their actions.

At the Air Force Academy, the required philosophy class teaches ethics and is augmented by the CCLD’s seminars. The CCLD, as well as most of the officer training at the Academy, operates within a four-level system. The four levels of personal, interpersonal, team, and organization (PITO) reflect the application of ethical standards starting within the individual then expanding influence outward to increasingly larger groups (Fig. 8.2). The CCLD’s seminars are organized according to the PITO model, beginning with personal goals and values and ending with observing and enforcing values at an organizational level. Engineers as well are responsible for justice within the organization. However, before recognizing and enforcing values and justice within an organization, they must be proficient at a

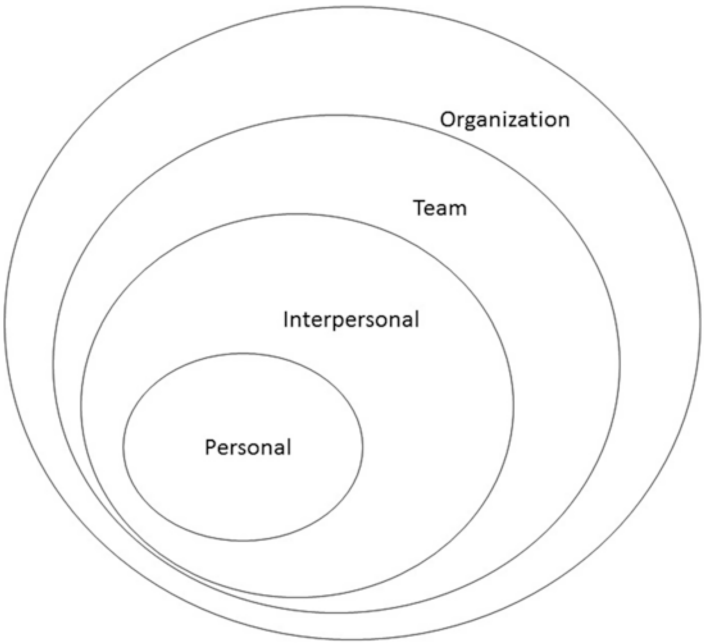

Fig. 8.2 The PITO model

personal level. As William Penn says in a quote memorized by Air Force Academy officer candidates, “No man is fit to command another who cannot take care of himself.” The ethics class itself could be taught within the PITO model, beginning with questions of justice within the context of the individual person. What does justice look like in your personal actions? What are the effects of justice and injustice in your personal decisions? What does justice look like in your interactions with other people? In the actions of a team and your actions as a team member and leader? What does a just organization look like? An unjust organization? What is your role within these organizations? Plato provides the foundation of asking these types of questions through his dialogues and images. His method easily fits into the PITO model, already being used at the Academy to teach and train officer candidates.

At the end of the day, there is no one easy answer, no danger-free option. However, if people care about discovering truth, about doing what is right, we are confident that better decisions will be made. The engineering field is no exception. Engineers must be trusted to make good decisions. Training and inspiring engineers to analyze their actions and situations, seeking the good and true, and practicing what is right will enable them to navigate even murky waters and make sound decisions.

The artifactual “honor code” has been adapted to the public university, though with less authoritative overtones, with some success. The focus has been on the congruency between espoused morals and actions. The education for behavior must combine not only theory and case study but also situational and experiential learning. It has been observed that a growing proportion of university students do not have a history of work experience to draw from when discussing ethics and proposing behaviors for case studies. US military colleges put students in challenging situations which gives them a realistic laboratory for experiential learning. ABET requires masters’ level programs in SHE to provide a realistic, “applied science project or research activity,” demonstrating mastery (ABET 2017a). These are often met by either a research thesis or an internship with industry. Even with a required field experience, the point is that a realistic stressful experience which requires the student to exercise judgment and work in a group is useful but rarely delivered outside the military class realm. For these engineering and SHE students in particular, it would be exceedingly useful not only to learn how to do something, but more importantly how to make decisions on what to do in the first place. This is particularly important for SHE risk education among engineers. Often SHE risk control measures make processes take longer and cost more. Organizational pressure often works against good SHE decisions, and the rising generation of undergraduates outside of military institutions may not be equipped to defend against withering interpersonal or organizational pressures.

We propose a method of classical philosophical instruction and discussion starting with Plato to help students consider the question, “What is justice?” The course would then move on to use a values-based construct such as from Aristotle, followed by realistic role-playing or other experiential-based learning experiences to help students think through difficult SHE decisions and moral dilemmas. This will

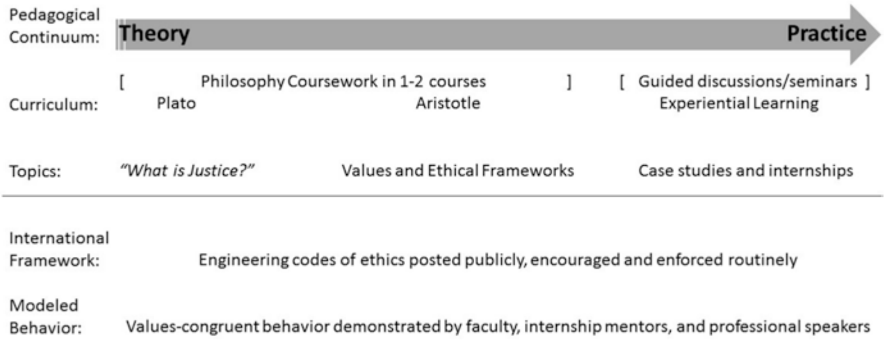

Fig. 8.3 Conceptual framework for engineering ethics curriculum

form a basis for an application course exploring artifactual and values-congruent behaviors to help students develop their personal moral code in light of established SHE and general engineering societies' codes of ethics. Institutions and programs will vary, so that the instruction could be done as one or two semester courses with a capstone discussion or project. It could also follow the military college model with one philosophy course and seminars throughout the undergraduate program allowing for discussion and application of the values-based construct. A simple visual aid is given in Fig. 8.3.

Further, engineering academic departments should publicly post internationally accepted ethical standards (artifacts). Finally, and most importantly, engineering faculty, internship mentors, and invited guest speakers must demonstrate integrity (values-congruent behavior) personally and professionally. This, combined with efforts to engage students with engineering professional associations, will help build a culture where ethical standards are exercised and reinforced.

Conclusions

There are shortcomings from an imposed ethical standard without sufficient philosophical education and development. Students and early professionals may not have fully embraced the ethical standards and may consequently fall into values-incongruent behavior. Likewise, there are problems with classroom theory lacking the experiential learning wherein students must actually make a decision and examine the consequences. The proposed combination of philosophy and application is expected to bear improved outcomes with graduates of engineering programs adopting ethical norms not out of imposition but out of resolution that their personal moral principles agree with engineering ethics. This would lead to more values-congruent behavior where engineers and SHE students across societies will act first to protect the public good. While this effort may require partnerships with university philosophy departments, and curriculum revision to include extra coursework and experiential learning, it is anticipated to bear good fruit for future generations.

Disclaimer: This chapter is the work of the authors and does not represent the policy or position of the United States Government, the United States Department of Defense, the United States Army, or the United States Air Force.

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Chapter 9
Factors Affecting the Success of IT Workforce Development: A Perspective from Thailand's IT Supervisors and Internship Students

Veeraporn Siddoo, Jinda Sawattawee, and Worawit Janchai

Introduction

Thailand is one of many countries which have introduced a 20-year national plan focusing on the development of a digital economy (Pooparadai 2016). The vision and strategy of the plan emphasize the digital foundation, digital inclusion, and digital transformation, and in the last phase of the plan, the Thai Ministry of Digital Economy and Society expects the country to be among the global digital leadership (Bukht and Heeks 2018; Nectec, Nstda, Most 2011; Pooparadai 2016). The IT workforce is one of the critical variables which can help to drive the development of a digital economy (Baller et al. 2016).

But today, Thailand is facing a situation in which there are insufficient IT workers. The Thailand National Statistical Office (2013–2017) published the results of a survey reporting the shortage of digital labor, and Table 9.1 shows the demand for IT workers and the number of IT graduates for the 5 years from 2013 to 2017, which indicates that demand for IT workers has been more than 10,000 persons in every year. In particular, in 2017, the number of workers demanded reached 45,055 persons.

While the data in Table 9.1 shows that the country has been able to produce more than 100,000 IT graduates per year, the actual situation has been that demand has exceeded supply. The apparent excess of IT graduates has been unable to fulfill employers' needs (Siddoo et al. 2017; Song and Tang 2016). This apparent paradox motivated the research reported in this paper which investigated the factors affecting the development of the IT workforce with respect to IT-related industries.

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Table 9.1 Demand for IT workers and number of IT graduates between 2013 and 2017

	Year				
Number of persons	2013	2014	2015	2016	2017
IT workers demanded	19,065	16,837	13,169	17,674	45,055
New IT graduates	101,263	130,723	108,444	149,369	113,874

In general, being successful in one's career means being continuously employed throughout one's working life (Adamson et al. 1998). But in the digital age, patterns of employment have changed (Leahy and Wilson 2014). Flexible employment including part-time and contracted work, and freelance working are increasingly common (Benzing et al. 2009; Leahy and Wilson 2014). Career success in a situation of increased job diversity can be defined as the ability of a person to achieve their work goals during their working experience (Gunz and Heslin 2005; Judge et al. 1995). Based on these two views of career success, the research reported in this paper, therefore, focused on determining the factors which affect the development of the IT workforce and result in the outcomes of individual learning and success.

Previous studies have investigated only the factors which are relevant to employee development. These factors include:

Individual factors: personal capabilities that affect work and self-development, such as soft skills, interpersonal skills, technical skills, IT career skills, and work experience (Asgarkhani and Wan 2007; Debuse and Lawley 2009; Finch et al. 2013; Md Saad et al. 2013; Radermacher and Walia 2013; Stevens and Norman 2017).

Workplace factors: features of the workplace and the people in an organization that affect employees both physically and mentally, such as the working environment, working atmosphere, working culture, office facilities, and team members (Asmui et al. 2012; Chandrasekar 2011; Earle 2003; Greening and Turban 2000; Hameed and Waheed 2011; Haynes 2008; Jain and Kaur 2014; Kim and McLean 2014; Njoroge and Yazdanifard 2014; Roelofsen 2002).

Job clarification: the precise job description and working procedure, such as job characteristics, career growth, and human resource management (Coetzee and Stoltz 2015; McMurtrey et al. 2002; Quan-Baffour and Arko-Achemfuor 2013).

Training system: experience and guidelines that affect employee empowerment, such as training systems and mentoring (Craig et al. 2013; Lapointe and Vandenberghe 2017; Minter and Thomas 2000; Pan et al. 2011; Raabe and Beehr 2003; Ragins et al. 2000).

Nevertheless, no previous study has researched the critical factors related to IT workers' development in the context of Thailand, based on the views of IT companies and workers' experience. Therefore, it was considered worthwhile to explore this area. The study addressed two questions:

RQ1: What are the success factors and the obstacles to the development of the IT workforce in Thailand?

RQ2: What can be done to assist future members of the IT workforce to reach the standards required for a successful IT career?

A qualitative methodology was used to answer the research questions. Professional supervisors working close to IT careers and students who have experience of IT and related industries were asked to join interview sessions. The findings indicated the factors affecting the development of the IT workforce in Thailand. The study discusses the results based on both the success factors identified and obstacles to development and finally presents a model as a set of guidelines for practitioners.

Literature Review

Career patterns in information and communications technology have been disrupted in the digital age (Atkinson and McKay 2007; Ritzer and Jurgenson 2010). New technologies and business models tailored to the needs of consumers are directly affecting the profession (Gretzel et al. 2015; Leahy and Wilson 2014). IT workers need to constantly adapt to be able to work in this diverse field (Breivik 2005). Previous studies have considered personal development and the factors and obstacles encountered in achieving performance and learning outcomes. The four broad groups of factors influencing employee development are as below:

Individual Factors

Asgarkhani and Wan (2007) investigated the key attributes affecting IT careers. The perception of employers and IT students were explored. The essential characteristics from the organization were found to be communication, people relations, teamwork, leadership, attitude, self-motivation, attention to detail, organization, mentoring ability, and customer focus. On the other hand, from the perspective of students, being an IT worker required a focus on problem-solving, communication skill, attention to detail, organization, and people relations. Debuse and Lawley (2009) investigated ICT job advertisements in Australia and the USA to establish the key attributes that IT workers should have, based on employer demands. They analyzed the data using text mining techniques to establish industry demands, which broadly fell into six categories: experience, technology skills, people skills, business skills, theoretical skills, and miscellaneous skills. It was found that employers focused mostly on employee experience and technological ability in IT-related areas and paid less attention to theoretical knowledge. Also, Finch et al. (2013) studied graduate employability and the skills required by the IT industry using a qualitative approach, finding that employee competencies, particularly in the soft-skills category, were most needed, followed by problem-solving skills, pre-graduation experience, functional skills, and academic qualifications. Based on the findings of Md

Saad et al. (2013) and Radermacher and Walia (2013), employers often need soft skills more than knowledge of academic theory, for example, communication and personal skills were mentioned most often as the attributes necessary, and employers required practical IT techniques and the ability to apply knowledge and technology to work based on individual competency. A recent finding from Stevens and Norman (2017) indicated that soft skills are essential. They analyzed the job market through focus group interviews, finding that individuals' soft skills could help employees to learn fast and to work smoothly within a team. However, employers in the IT industry did not undervalue fundamental knowledge and expected candidates to be able to apply in-depth technical knowledge and soft skills to develop themselves and to help organizations to grow. McKenzie et al. (2017) conducted a thematic analysis of the skills that students expected to achieve while studying and after graduating. The researchers found that IT students considered that in the short term, skills such as communication, IT technical ability, problem-solving, and teamwork ability were vital in achieving their ambitions regarding their careers, whereas for long-term success, leadership and management skill were key. The study also investigated the barriers to self-development with potential future workers indicating that lacking confidence could lead to individuals failing to improve their efficacy.

Workplace Factor

One of the key drivers for the success of an organization is the quality of the employees (Glazer 1998; Meyer 1991; Ruggles 1998). The working culture and environment have been studied, and it has been found that there are positive relationships among employee motivation, development, and performance. Hameed and Waheed (2011) suggested that an organization's culture affects employee performance. A positive culture induces employees to be open-minded and to participate with the team and can also increase employee self-development. Greening and Turban (2000) investigated how the image of a company can influence the quality of candidates who apply for a job. Good organizational corporate social performance can reflect positively on an organization's values (Backhaus et al. 2002) including fostering good teamwork and a good working environment (Chandrasekar 2011) which in turn affect worker productivity. While organizations look carefully for employees that they want to employ, quality workers also search for an organization with which they want to work (Greening and Turban 2000). Moreover, the workplace environment and facilities have also been found to have an impact on employee productivity and development (Chandrasekar 2011; Haynes 2008; Asmui et al. 2012). By contrast, a poor work environment and office facilities, such as a poorly designed working area, uncomfortable chairs, insufficient light, or overwhelming noise, would probably cause a decrease in working performance (Asmui et al. 2012; Awan and Tahir 2015; Nawaz et al. 2017).

Job Clarification

A clear definition of job responsibilities and scope of work has a direct impact on the understanding and attainment of workers. Coetzee and Stoltz (2015) found that a proper explanation of the work scope and clear identification of organization goals and career progression and growth opportunities affect human resource development and employee retention. Similarly important are role congruity, defined processes, and job aids (Chandrasekar 2011). Many organizations arrange an orientation day to describe the company and job details. McMurtrey et al. (2002) found that activities during an orientation day, which highlighted technical details, helped IT professionals to appreciate their jobs more. On the other hand, the lack of a clear explanation regarding career path and opportunities for progression would reduce professional satisfaction and happiness at work (Quan-Baffour and Arko-Achemfuor 2013). Moreover, organizations should encourage their employees to be involved in planning work (Chughtai 2008) rather than simply conveying instructions about the work to be done.

Training System

New employees are often inexperienced and expect to be trained by experienced workers at their workplace. Employee training is a benefit for an organization since it ensures that individuals will have the ability to perform their work (Craig et al. 2013). Moreover, training also promotes better and more responsible attitudes (Craig et al. 2013; Pan et al. 2011). Many organizations set up mentoring programs for new employees, in which an experienced person in an organization teaches, coaches, or gives advice to an inexperienced person (Kram 1988). Mentoring duties can be both job specific or relate more generally to working life. In practice, some organizations set up employee training systems for a period followed by a mentoring program involving face-to-face participation. Proper training and mentoring systems have been found to significantly affect employee satisfaction (Craig et al. 2013; Ragins et al. 2000). Raabe and Beehr (2003) found that a mentor who was a supervisor or coworker could help increase an employee's job satisfaction, and improve staff retention and organizational engagement. Similarly Ragins et al. (2000) found that a positive mentor relationship could lead to a new employee having a positive attitude and this affected their working performance. However, a mentoring program may cause a negative result among some individuals (Bozeman and Feeney 2008; Eby et al. 2008) and might lead to increased turnover (Lapointe and Vandenberghe 2017). In summary, as in any form of counseling, organizations should ensure that mentor and mentee characteristics match satisfactorily (Minter and Thomas 2000) and should also clearly identify the expected goals before setting up a mentoring program.

Research Methodology

Study Participants

The population was divided into two groups: (1) organizations in Thailand who employ IT workers and have experience in supervising IT students and (2) IT students who were studying information technology and related subjects in Thailand and were participating in WIL programs. Companies and students who joined a WIL program with university A in the first and second semesters of 2018 were selected to be interviewed for this research. A summary of the sample groups and the total number of participants is shown in Table 9.2. The details of organizations and students are shown in Appendices A and B, respectively. The diversity of positions and types of industries involved in the interviews ensured that the findings reflected the opinions of experienced persons.

Research Instruments and Their Reliability

The research was conducted based on semi-structured interviews based on a set of questions consisting of two main sections: (1) demographic questions and (2) research questions. The questions were generated based on assessed learning outcomes (Nusche 2008) and motivation. Semi-structured interview guides were created and the questions were organized based on core WIL processes: recruitment, working practice, and assessment. At each stage, reflection and discussion questions were used to focus the interviewee on the workforce development process. The interview questions were as follows:

Questions for organization representatives	Questions for students
Recruitment process	
On what basis do you consider a candidate? What skills do you expect from a new employee? What kind of facilities and environment do you provide for your employees?	What are the strongest skills or abilities that support your working position, and what are your weaknesses? How did you select the workplace for your work practice? What kind of facilities and environment do you expect in the workplace?
How significant is cooperation with the university from your perspective?	How did/does university cooperation affect your recruitment and working practice?
Practice process	
How do you manage your working role as a mentor? How are new IT employees supervised?	What knowledge and supervision do you expect in the workplace? How do you learn during work practice?

Questions for organization representatives	Questions for students
What skills were important to IT workforce development?	What skills are important to your position?
Assessment process	
How do you assess internships? How do you measure learning outcomes?	Do you think you are successful in your work practice? Why/why not?
Reflection questions	
What did you learn and receive from the workforce development process? Did you encounter any problems or obstacles? If yes, have you already solved them and how? Do you still have any problems or obstacles? If yes, why has a solution not been found yet? Do you have a plan for what to do next? If yes, what is it?	

Table 9.2 Research participants

Sample group	Participants		Total
	Working in IT industries	Working in non-IT industries	
Companies	20	14	34
Students	64	17	81

The structure and content validity of the research instrument was verified by three IT professionals and three IT academics. The results were reasonable. The experts made some suggestions about the sequence of the questions.

Data Collection and Analysis Methods

The individual semi-structured interviews were conducted between 1 January 2018 and 31 May 2018 and lasted not more than 2 hours each. The interviewer was a WIL expert who had been trained by supervisors accredited by the Thailand Office of the Higher Education Commission. The face-to-face interviews with representatives of companies providing WIL work placements and students undertaking WIL generally took place at the company premises during the WIL assessment period. Where an in-situ interview was inconvenient, a telephone interview was arranged and held.

The data was analyzed using content analysis. Themes and categories were created and the interviews coded. To avoid misunderstandings, three researchers and cooperating experts discussed the outcome of the thematic analysis and agreed with the final results. The analysis was conducted by reading the interview transcripts and coding them to themes and categories. Because of budget constraints on using qualitative software programs, the analysis was conducted using a spreadsheet with document software tools to establish word frequency and thus code the themes.

Findings and Discussion

In this section, the study's results will be presented based on the research questions in the Introduction, and they will be discussed concurrently. The opinions and suggestions made by the 34 supervisors and 81 students in IT career are very similar. Both expressed the opinion that career success for IT workers was largely achieved based on self-learning and being able to complete work tasks. This result was consistent with the findings related to career success of Gunz and Heslin (2005) and Judge et al. (1995).

RQ1: What are the success factors in, and the obstacles to the development of the IT workforce in Thailand?

The successful development of the IT workforce depends on many factors. The research findings show that there are success factors that need to be addressed, but that individuals also need to have the necessary commitment to their careers. In analyzing the transcripts, *moving towards an IT workforce* was coded as the main category. The categories and subcategories are presented in Fig. 9.1.

People

The people affecting the development of the IT workforce can be classified into three main groups: workers, mentors, and academic lecturers.

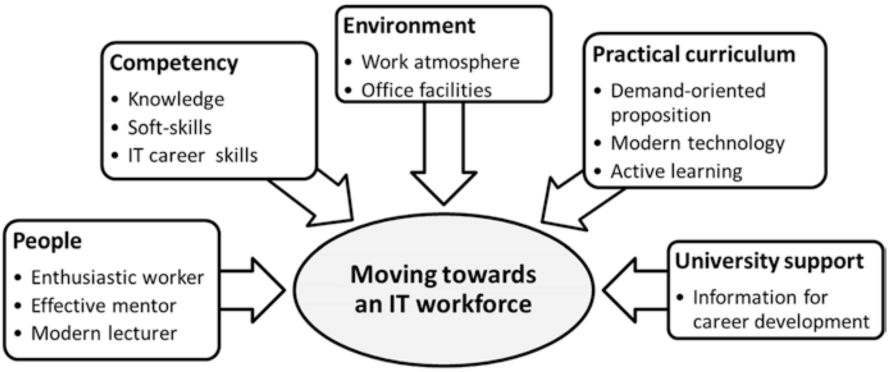

Fig. 9.1 Factors affecting the success of IT workforce development

Enthusiastic Worker

An IT worker should have enthusiasm and a passion for working in an IT career. Most IT professionals agreed that a person who showed interest in work and keenness to be employed was often selected, even though they might not have strong technical skills. Although the IT professionals agreed that IT knowledge and technical ability were essential in the ICT field, they nevertheless believed that a desire to work would enable individuals to learn by themselves. Similarly, many IT workers had discovered that their commitment was a key driver of success. This result is consistent with the study of Asgarkhani and Wan (2007) which found that attitude and self-motivation were the key factors in successful workforce development and that these qualities corresponded to the soft skills that were frequently mentioned by employers (Finch et al. 2013; Md Saad et al. 2013; Radermacher and Walia 2013).

IT professionals' opinions: *"We select a worker by considering a person's intentions" (P22)*, *"If we have to compare two applicants, we will choose the one who has experience and shows an intention to learn rather than a person who only has academic knowledge" (P2).*

Internship students' opinions: *"My success comes from my attitude and willingness to offer ideas to my supervisor" (S24)*, *"I have tried to troubleshoot problems when I am working at a customer site. I am very proud of that" (S15).*

On the other hand, if an individual did not pay attention to the job assigned to him, he might miss the opportunity to improve himself.

Supporting statements: *"A person who does not show a good attitude in work will not gain employment and will not be successful" (P6)*, *"Not trying to self-study and hoping to rely on others, this behavior often leads to a lack of ideas about solving problems" (P9)*, *"New staff who do not act responsibly, and are poor at communicating will not usually be retained by the organization" (P15)*, *"People who refuse to learn are often unsuccessful in this field" (P2).*

Effective Mentor

The ability to coach or teach is an influencing factor on employee development and performance (Craig et al. 2013). A mentor or supervisor should have sufficient experience to provide knowledge to a learner. The results from the interviews suggested that in transferring knowledge, both a mentor's professional qualifications and sharing behavior were needed. Most supervisors mentioned that mentors must be properly trained and that was one of the success factors in IT workforce development. This supports the findings of Ragins et al. (2000) and Raabe and Beehr (2003) that mentoring systems and mentor characteristics have an effect on employee effectiveness. However, mentors often have their own coaching style, but must adapt their teaching strategy to the learners' needs. The students, who would be IT workers in the future, also expected to be coached by a mentor while gaining work experience, and wanted the mentor to willingly convey knowledge and teach them calmly. It has been previously noted that a mentor's negative attitude can affect the curiosity of the learner (Eby et al. 2008).

IT professionals' opinions: *"We emphasize the process of mentor assignment, we have to choose the right person for a new employee" (P21)*, *"A good mentor must have experience, teaching skills and adequate time to answer a learner's questions" (P23, P25, P28).*

Internship students' opinions: *"The mentor helps us to understand how to apply theory to a working task" (S11, S65)*, *"The mentor has taught me willingly and has tried to answer our questions simply" (S33, S48, S81).*

On the other hand, mentors who lacked skills and time adversely affected employee's learning and feelings.

Supporting statements: *"The mentor only assigns tasks without explaining anything and I do not know what to do" (S19)*, *"The mentor does not have the time to coach me and discuss things with me" (S20)*, *"The theoretical teaching method does not help us to understand" (S70).*

Modern Lecturer

Normally, inexperienced workers obtain knowledge and develop their ability through higher education and it is the role of university lecturers to teach practical responsibilities. Lecturers who can teach theory as well as practical skills are very much in demand. Most students commented that teaching theory was important and thought that an inductive style of teaching without practical experience was not appropriate for the digital age. Some supervisors mentioned that lecturers with practical experience of working in the IT industry could improve learning outcomes. This issue was related to the finding of McKenzie et al. (2017) that academic problems were a barrier to career development.

IT professionals' opinions: *"We hope that the university will realize that teaching both theory and practice is important and take action to do so" (P2, P6). "Lecturers must teach both theories and the ability to solve problems within the industry" (All supervisors).*

Internship students' opinions: *"We want our teachers to give us many examples because a visual representation makes us understand better" (S27)*, *"In the classroom, the teachers should use case studies or give problem cases to the student to solve because more practice can increase a student's confidence when working" (S80).*

Additionally, teaching methods which do not make the learning purpose clear or provide proper explanations often affect the students' self-development.

Supporting statements: *"We are not clear about the subject's objectives" (S3)*, *"The teacher doesn't suggest what assignments we should do and sometimes the* *results do not meet her needs" (S17)*, *"In the classroom, 3 hours of listening makes us bored and we forget the lesson pretty quickly" (S1).*

Competency

Competency is usually used as a measure of learning outcome. Quality IT workers acquire many skills. The result of the content analysis suggested a division of competencies into three groups: knowledge, soft skills, and IT career skills.

Knowledge

IT foundation skills and theoretical knowledge were highlighted as essential knowledge for IT workers. Understanding things such as computer fundamentals, database management, or basic programming and logic were identified as essential for IT careers, and the supervisors strongly recommended that future IT workers should become familiar with fundamental knowledge before graduating. Some supervisors expected business knowledge to enable new employees to be able to negotiate with customers. Most students, whose working tasks related to customer data and other information, considered database management to be an important skill. At the same time, a new technology, business trends, and work-related issues were mentioned as contributing to IT workforce development and these findings from the interviews were in agreement with the previous studies of Finch et al. (2013), Radermacher and Walia (2013), and McKenzie et al. (2017).

IT professionals' opinions: *"We can easily teach new staff when they have strong basic knowledge of IT" (P27)*, *"There is a huge difference in learning between people who have strong knowledge and those who do not have it" (P28)*, *"Basic coding logic is needed in IT careers. It can help new staff to explore problems with software programs or even to create new programs" (P4).*

Internship students' opinions: *"Basic knowledge of website design and computer components helps us to complete working tasks" (S70)*, *"Being able to read the program code enables us to fix errors" (S30)*, *"If we could turn back time to when we were at school, we would study basic programming and algorithms hard" (S32).*

Similarly, an insufficient knowledge related to IT careers would cause new workers to learn slowly and could affect their employment.

Supporting statements: *"Mentors spend most of their time teaching basic IT knowledge. In the end, new employees will lose the opportunity to learn the next difficult thing" (P10)*, *"Those who do not seek new knowledge or approaches related to the job will not achieve career growth" (P10).*

Soft Skills

Both the supervisors and students discussed this type of skill. The findings can be separated into behavioral skills, such as attitude, adaptability, innovation or life-long learning, and interpersonal skills, such as communication or teamwork. The supervisors indicated that they expected the new staff to have a good attitude and an open mind including being motivated to help the team to achieve its goal. Further, the students also rated teamwork, generosity, and communication as essential competencies. Many students wanted to learn to be more patient when learning difficult tasks and admitted that learning hard things required a lot of time and patience. The importance of soft skills found in the interviews was in agreement with previous studies (Finch et al. 2013; Md Saad et al. 2013; Stevens and Norman 2017) but the interviewees emphasized soft skills in the IT context such as communication using IT terms.

IT professionals' opinions: *"We love to work with patience, and have to sacrifice, knowing that the firm will benefit" (P8)*, *"Individuals who have leadership skills and love to learn can easily understand the business and our customers' needs" (P3, P4, P5)*, *"New employees who can analyze details of the work in both technical and social terms are very likely to progress in their careers" (P3).*

Internship students' opinions: *"Teamwork skill helps me to work with my mentor and other colleagues" (S12)*, *"I apply my life-long learning and searching skills in my work such as using the right keywords when searching on the Internet to find a solution" (S13).*

On the other hand, oral and written competencies were pinpointed as a weakness of young IT workers and it was observed that workers who were not enthusiastic would always be overlooked by the company.

Supporting statements: *"Often, new employees cannot explain to the team what they have done" (P26)*, *"Some trainees do not know what the appropriate language should be, even in writing formal emails" (P25)*, *"I regret that sometimes I accidentally speak inappropriately to customers" (S15).*

IT Career Skills

After graduating, the knowledge and skills learned by students at university will be applied in the jobs. This finding suggests that in the development of the IT workforce, skills such as those relating to hardware and networks, IT skills for work and software or mobile applications were directly related to success at work. The supervisors mentioned that in addition to basic IT knowledge, in-depth IT skills were required (Mckenzie et al. 2017). In general, new applicants with strong IT skills were selected for employment. Ninety percent of the students who were interviewed had the same opinion about career success, that competencies such as programming language skills for work, IT service management skills, and software development were influential in their being able to gain employment. This finding was consistent with those of Finch et al. (2013) and Md Saad et al. (2013) that employers focused on career skills.

IT professionals' opinions: *"Of course, we can teach in-depth skills to new employees. But it is better if we can choose someone who can work immediately without being taught" (P29)*, *"Programing and application skills are essential in IT careers" (P19)*, *"There are emerging IT technologies, programming languages as well as new business models, and we need people who can adapt themselves to work with them" (P19).*

Internship students' opinions: *"Program analysis, coding techniques or interface design are all acquired while working" (S35)*, *"Anyone who can use a variety of software programs has an advantage" (S18)*, *"Supervisors expect us to use software packages fluently to increase productivity" (S19).*

On the other hand, people who did not have professional skills would not be promoted in their careers.

Supporting statements: *"In my workplace software applications and technologies are used; we are not prepared for that situation. We should practice more" (S18, S19)*, *"UX/UI and user experience design concepts are used most at my workplace and my supervisor assigns jobs related to those theories to me. I am not strong on those concepts so I cannot finish the work in time" (S60).*

Environment

Today, organizations focus more on the workplace and the design of the working environment as well as providing tools and equipment to help employees to complete their tasks. The findings could be divided into two categories: work atmosphere and office facilities.

Work Atmosphere

According to the interview results, most workers had to work 8 hours per day. Many employees used a computer for at least 3 and as long as 8 hours per day and spent time on the Internet depending on their duties. The working atmosphere has been noted to be an important element that affects the feelings and emotions of workers (Chandrasekar 2011; Haynes 2008; Asmui et al. 2012). The working environment affects task performance, productivity, and creativity (Asmui et al. 2012). New workers expect to work with a compatible and creative team. The future IT workers considered the environment as one of the factors when selecting their workplace. Many organizations also realize that factor to be important and try to create a corporate culture which promotes productivity. The research findings in this study were the same as those of Backhaus et al. (2002), who found that the image and the working atmosphere affected the progress of the work and the satisfaction of the employees.

IT professionals' opinions: *"We respect our staff's opinions. We create a social sharing culture in the organization" (P5, P6)*, *"We organize scrum meetings weekly to get an update on each team's work progress and to share information with other teams" (P12)*, *"The atmosphere for teaching our new employees is not stressful because we understand how to teach inexperienced workers" (P33).*

Internship students' opinions: *"I chose this workplace because of the job description and the friendly mentor and colleagues" (S7)*, *"I want to work with a modern company which has a good organizational structure" (S19)*, *"The organization has a good profile. And after the job interview, I found that the job is interesting, and the working team makes me more energetic" (S69).*

On the other hand, many employees identified experiencing undesirable working conditions such as a command-system culture, a lack of teamwork, or non-challenging work.

Supporting statements: *"I feel disappointed that my mentor did not teach me and just left me to learn by myself" (S19)*, *"I am made to do too much document work despite my position as a programmer" (S20).*

Office Facilities

Workplace equipment such as a working table, chair, computer, and automated office tools can assist productivity. Also, the physical design of the general environment such as the working layout, lighting, and temperature and noise control were mentioned. The results were similar to those found by Asmui et al. (2012), Awan and Tahir (2015), and Nawaz et al. (2017), who all mentioned the importance of applying ergonomic design in the workplace.

IT professionals' opinions: *"We provide a laptop computer to all new staff" (P13)*, *"Our company is a mobility office and workers can choose their workstation" (P18)*, *"Our experience is that workplace arrangements and concerns about lighting and ventilation affect people's enthusiasm for their work" (P18).*

Internship students' opinions: *"I am proud of my office because the company gave me a new hi-spec computer" (S62)*, *"The workplace is beautifully arranged with workstations, a chat room and a conference room and the equipment is very modern" (S62).*

On the other hand, overlooking the provision of a proper working environment might make the employees less willing to work and decrease work quality.

Supporting statement: *"The workplace is too small, and I feel uncomfortable" (S35)*, *"I am jealous of my friend whose company gave her a new notebook for her work" (S72).*

Practical Curriculum

Most IT worker competencies were firmly and profoundly based on instruction at university-level. Developing an appropriate curriculum encourages learners to learn through understanding rather than simply memorization. The study's findings were divided into three groups of opinions relating to practical curriculum design: demand-oriented proposition, modern technology, and active learning. These factors were also cited by Finch et al. (2013) in relation to findings on the issue of academic reputation.

Demand-Oriented Proposition

Many organizations thought the existing curriculums were appropriate for training the future IT workforce. They considered that universities should pay attention to trends and add new lessons or subjects that are relevant to market demand when reforming courses and that curriculum design should be based on real need.

IT professionals' opinions: *"Universities can help with the labor-shortage problem by increasing the content related to industry needs in their lessons" (P30)*, *"Universities should invite companies to participate in curriculum design" (P28).*

Internship students' opinions: *"I have applied my final project's experience to my work" (S1)*, *"Practical experience can fill the gap between a student's ability and the company's demands" (S38).*

On the other hand, if universities ignored industry demands, they might not produce graduates who met the labor market's requirements.

Supporting statements: *"I prefer an up-to-date course or a short course about new programming languages" (S24)*, *"The faculty should pay attention to providing relevant skills to match the industry demand" (P22).*

Modern Technology

The findings in this area showed that students who were from the Internet generation always used a search engine to find a solution to problems because they are surrounded by technology and innovations. Technology is a factor that helps to develop an employee's ability. Learners expect universities to focus on the lesson's context and to apply technology in the teaching approach. The supervisors also suggested that the use of technology could help to decrease the time spent training staff.

IT professional's opinion: *"Our company buys many online courses so that our staff can learn by themselves" (P11).*

Internship students' opinions: *"Information sharing via the Internet helps me to solve problems" (S50)*, *"The use of simulation programs is interesting. It helped me to quickly understand color design"* (S65).

On the other hand, neglecting the use of technology resulted in slower development of knowledge and skills.

Supporting statement: *"I hope the faculty will invest in a variety of software which can be used as examples in the classroom" (S65).*

Active Learning

Teaching methods and increased experience have had an impact on learning because good teaching helps students to apply theory in their work. Project- or problem-based learning in the classroom were mentioned during the interview. The supervisors thought that active learning helped to increase students' critical thinking skills. Some students mentioned that they had presented their portfolios including their senior-year project and that this helped them to get hired.

IT professionals' opinions: *"We recommend that lecturers should focus on practical teaching by using customers' problems as case studies" (P15)*, *"The advantage of a problem-based learning approach is that the learner will learn faster because they are dealing with real situations. Moreover, organizations can simultaneously assess the ability of new workers such as what knowledge they use and how they solve problems" (P9).*

Internship students' opinions: *"My mentor gave me a customer case to handle. I had to deal with our customer and fix their problem while the mentor helped me and provided me with guidance. After dealing with the case, I learn many things such as technical and communication skills. I think this is the right way to teach students" (S42)*, *"The approach of encouraging new workers to dare to think and to present their ideas is a good practice" (S7).*

On the other hand, teaching methods focused on theory and knowledge without giving examples would inhibit learning by workers.

Supporting statements: *"I want to stress that the university should teach future IT workers by using case studies" (S18)*, *"Lecturers would rather invite a company representative to help conduct a problem-based class" (S77)*, *"There is a big difference in teaching approach between studying on campus and in an internship" (S1).*

University Support

The research highlights how understanding the IT industry's demands and the suitability of new worker's skills influences the development of the IT workforce. Most students were looking for career direction and wanted collaboration between companies and their university. Information about career development including a properly prepared learning environment was highlighted. This finding was supported by the studies of Finch et al. (2013) and McKenzie et al. (2017) who found that a lack of academic cooperation might cause students to miss opportunities.

Information About Career Development

The supervisors explained that understanding the meaning of an IT career had a profound effect on students' decisions when they graduated. Academics should research to investigate what new demands the IT industry presents every year. Providing accurate information to students would increase understanding and encourage greater professional interest. In the view of the future IT workers, they not only need up-to-date information but also lessons to improve their skills and expertise.

IT professionals' opinions: *"Universities must create networks to encourage people to join the IT industry workforce" (P19)*, *"Companies have a mission to work with universities to help them to fulfill the needs of the IT labor market" (P19).*

Internship students' opinions: *"Our university offered me the opportunity to be trained in a programming-related course that was conducted by IT professionals" (S26, S27, S28)*, *"For the final project, the university asked private companies to give us some customer requirements and also requested the same companies to assess the result of our project" (S26).*

On the other hand, some students said they lacked experience and skills because they did not know what was important.

Supporting statement: *"My major study did not pay attention to business requirements. But after my internship, I realized that marketing knowledge is very important in my area" (S14).*

RQ2: What can be done to assist future members of the IT workforce to reach the standards required for a successful IT career?

The goal of IT workforce development is improving the quality of workers and solving the country's IT labor shortage. The supervisors pointed out that without experience, individuals could not learn the necessary IT skills although most expected that IT workers would have self-learning ability. Three broad categories of suggestions were derived from the research findings. They were *digital/IT knowledge and context*, *innovative workplace and ecosystem*, and *consultancy and cooperation*.

(a) Digital/IT knowledge and context

To prepare the workforce for the IT industry, the correct understanding of the digital/IT context must first be built. Collaborators must discover information about industry requirements, job descriptions, career explanations, and the competencies necessary for new IT workers, and that information will need to be stored in a knowledge management system.

(b) Consultancy and cooperation

The questions faced by inexperienced workers are what to learn, how to learn, and also why to learn. They need guidance to help them develop and thereby to contribute to workforce development. Industry supervisors and academic instructors can help them answer the what, how, and why questions through the application of teaching experience. Universities and workplaces should together design teaching methods for future workers. Moreover, curriculums should be designed jointly and should be based on real industry demands.

(c) Innovative workplace and ecosystem

An appropriate environment encourages learning and helps the learner to be creative. Academics must prepare simulations of the working environment in the university classroom so that teaching fits students for their future roles. Also, supporting tools that can help increase the learner's interest should be used. On the corporate side, companies should create a pleasant working environment as well as other facilities for new workers and must not forget that social appearance and the community are important aspects of IT careers.

Based on the research findings, the ultimate goal of IT workforce development is to produce people who can self-learn and can work effectively. This finding is similar to that of Grow (1991) that self-directed learning should be the target of teaching by adopting a staged self-directed learning model. Figure 9.2 presents a schematic model of IT workforce development. The model combines three components: *influenced factors*, *development activities*, and *IT worker's learning stage*. *Influenced factors* affect the process of *development activities* and *learning stage*. Concurrently, activities that enhance worker performance have been necessary for human development.

Table 9.3 shows a four-stage learning model including examples of relevant knowledge and activities at each learning stage based on organizational best practice, and the examples were derived from the interview results.

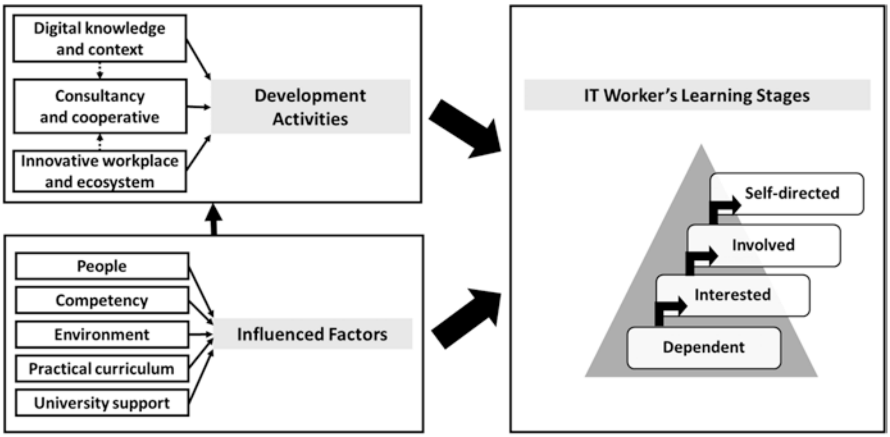

Fig. 9.2 Model of IT workforce development

Table 9.3 The four-stage learning model with examples of information and activities for IT worker development

	Support information and activities		
New IT worker's learning stage	Digital/IT knowledge and context	Consultancy and cooperation	Innovative workplace and ecosystem
Dependent	Theoretical information Definition of career Digital labor targets	Foundation teaching Example career and discussion	Physical: Working atmosphere Office environment and facilities Innovative classroom Technology and tools Learning resources Social: Social community The Internet community Seminars, Webinars
Interested	Importance of career Career competency Career path Digital industry and market growth	Experience motivation What, how, and why to learn Customer site visit Group discussion	
Involved	Essential competencies for problem-solving Case study and problems Practice lesson	Project group discussion Teamwork simulation Feedback management	
Self-directed	Customer requirement Real industry problems	Individual work Individual consulting Group discussion	

At the dependent level, new learners should focus on understanding careers in the digital/IT context and the knowledge necessary to work in them. The activities listed against the interested stage introduce the importance of IT careers, their challenges, and how the range of those careers is growing. Learners need to be guided as to the working atmosphere which they can expect and by preference they should experience practical learning as soon as possible. At the involved stage, there should be increased practical experience, and at this stage, case studies are essential and teaching should be based on industry problems, productive discussion, and teamwork. The last level is self-directed learning which focuses on problem-solving by the individual although there may also be some group work. The mentor must be able to provide counseling and guidance to the learner. The four stages of learning should be based on appropriate environments and an appropriate atmosphere including classrooms, working rooms, and corporate premises. Additionally, creating a learning environment, both offline and online, will lead to the sharing of information and experience that should lead to life-long learning.

All the people interviewed including the IT students mentioned that in the future, IT workers' abilities and success in their careers would be based on their efforts with mentors and lecturers performing mainly as facilitators. Workers' competencies combine various dimensions and to be a quality IT worker requires both academic and digital/IT knowledge as well as soft skills and IT careers skills. Moreover, to properly develop the IT workforce, all aspects of their education must be properly prepared. Applying the model to other industry can be done by considering the context that is necessary for a career group in that industry. The generalized approach is to find factors that affect the development of qualified workers then develop guidelines for promoting skills and expertise in the profession. The domain that is suitable for bringing the model to their adoption is another industry context that requires IT to drive business growth.

Conclusions

This research explored the factors that influence the development of the IT workforce. The qualitative study was conducted by interviewing 34 IT professionals and 81 IT students in Thailand. Content analysis of the interviews identified themes and categories relating to the factors providing the answer to the research question. The categories identified were people, competency, environment, practical curriculum, and university support, and the study proposed a four-stage model for the development of the IT workforce and identified activities and example tasks at each stage.

The findings and suggestions are useful for the future development of IT workers, as well as guiding higher education and companies who play a critical role in IT worker development. All concerned need to understand that both academic and practical IT knowledge is required by quality IT workers. Additionally, soft skills and digital careers skills are also needed. Moreover, workers who can learn quickly by themselves are needed by the industry. Future research should address the needs of a knowledge management system to assist the sustainable development of the IT workforce.

The main limitation of this research is that the study was conducted in Thailand with only a limited sample based on students who were part of WIL programs. The findings are therefore specific to the sample selected and also to both the time and the situation under which the data were collected.

Appendices

Appendix A: Demographic of Organizations

Participant	Position	Industry type	IT experience (year)	Mentoring experience (year)
P1	IT Manager	Tourism	10	Yes (>5)
P2	Founder	Technology, ICT	20	Yes (>5)
P3	IT Manager	Technology, ICT	17	Yes (>5)
P4	IT Manager	Technology, ICT	20	Yes (>5)
P5	IT manager	Technology, ICT	8	Yes (>5)

Participant	Position	Industry type	IT experience (year)	Mentoring experience (year)
P6	IT Manager/Founder	Technology, ICT	15	Yes (>5)
P7	IT Project Manager	Technology, ICT	20	Yes (>5)
P8	IT Specialist	Technology, ICT	18	Yes (>5)
P9	IT Specialist	Technology, ICT	18	Yes (>5)
P10	IT Technical and Sale Engineer	Technology, ICT	17	Yes (>5)
P11	Project Manager	Technology, ICT	12	Yes (>5)
P12	Sale Manager	Technology, ICT	15	Yes (>5)
P13	Senior Graphic Designer	Technology, ICT	12	Yes (>5)
P14	Senior Graphic Designer	Technology, ICT	15	Yes (>5)
P15	Senior Programmer	Technology, ICT	10	Yes (>5)
P16	Senior Programmer	Technology, ICT	5	Yes (>3)
P17	Senior Programmer	Technology, ICT	5	Yes (>3)
P18	Senior System Administrator	Technology, ICT	17	Yes (>5)
P19	Senior System Analyst	Technology, ICT	10	Yes (>5)
P20	Senior System Analyst	Technology, ICT	20	Yes (>5)
P21	System Engineer	Technology, ICT	10	Yes (>5)
P22	Senior System Administrator	Resources, Energy	17	Yes (>5)
P23	IT Manager	Property, Construction	17	Yes (>5)
P24	Senior IT Staff	Health, Medical Technology	20	Yes (>5)
P25	Chief of Board of Directors Section	Government, State enterprise	20	Yes (>5)
P26	Computer Technical Officer (expertise)	Government, State enterprise	20	Yes (>5)
P27	Senior Programmer	Government, State enterprise	10	Yes (>3)
P28	Assistant Vice President	Financials, Bank, Insurance	20	Yes (>5)
P29	IT manager	Financials, Bank, Insurance	21	Yes (>5)
P30	Senior System Analyst	Financials, Bank, Insurance	18	Yes (>5)
P31	Senior System Analyst	Financials, Bank, Insurance	17	Yes (>5)
P32	Senior System Analyst	Financials, Bank, Insurance	17	Yes (>5)
P33	Senior Tester	Financials, Bank, Insurance	17	Yes (>5)
P34	Software Engineer	Financials, Bank, Insurance	15	Yes (>5)

Appendix B: Demographic of WIL Students

Students' career groups	Interviewee number	Total	Industry sector		Gender	
			IT	Non-IT	Male	Female
Digital content/internet/SEO/marketing	S1–S14	14	9	5	7	7
Hardware/network	S15–S16	2	1	1	2	0
IT auditing/testing/QA	S17	1	1	0	1	0
MIS	S18–S23	6	2	4	5	1
Programming	S24–S65	42	40	2	30	12
Web design/graphic	S66–S81	16	11	5	4	12

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Chapter 10
A Collaborative and Interdisciplinary Approach to Bring Closer a Curriculum to Local Employers' Needs

Laurent Veillard, Stéphanie Tralongo, and Michel Le Nir

Introduction

Since the mid of the 1990s, Qatar is engaged in an economic diversification strategy to move away from an economy strongly based on gas and oil production (Qatar National Vision 2030 2008; Srour-Gandon 2013). The objective is to set up a knowledge-based economy, consisting in developing infrastructures and high-level international services in the fields of cultural and sports tourism, banking, telecommunications, transport, etc. Such an objective requires a highly efficient education system, especially at tertiary level where students can develop the knowledge, skills, and attitudes expected by the local labor market and overcome the excessive recourse to qualified foreign labor (Berrebi et al. 2009). Qatar University (QU) has been established in 1977. During several years, it was the only higher education institution in the country. But since the mid-1990s, the Qatari authorities have carried out several actions to provide the country with a more diversified and efficient higher education system: creation of an agency for research and education (Qatar Foundation); establishment of an international campus hosting several foreign university branches (Education City); development and reorganization of Qatar University; and more recently creation of a high-level research university (Hamad Bin Khalifa University (HBKU)), based on the Anglo-Saxon Graduate School model (Moini et al. 2009; Khodr 2011). This important transformation of the tertiary education provision was followed by an extremely strong and rapid increase in the number of students: 83% increase in only 5 years according to the figures provided by the Ministry of Development Planning and Statistics[1] (15,352 students in 2010/2011; 28,106 in 2014/2015).

[1] http://www.mdps.gov.qa/

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Despite these numerous initiatives, a gap between academic and professional spheres is still noticeable. Big efforts have been done by Qatar University, for instance, which welcomes the largest number of university students in the country, among them a large percentage are nationals. The university has developed collaboration with employers and stakeholders, who take part of several of the university committees at different levels (university, colleges, departments, etc.) and give a professional feedback from the field, important for the university curricula. A further interaction with the industry stakeholders is however still needed to shape future Industry 4.0 curricula and adapt some of the existing ones which particularly seem more focusing on academic disciplinary knowledge. As a result, students will be better prepared for their working life and will better fit with the growing needs of the industry. Considering the increasing and sustainable needs of high-qualified workers (middle-level managers, engineers, managers) in the country, the firms cannot count anymore mainly on the highly qualified expatriates for their most skilled jobs as they did since decades.

As in many highly growing countries, the lack of local competences in the IT field is particularly glaring. Especially, the government wants to make the country a leading player in the field of digital innovations and services and hopes that this objective will not be based solely on foreign labor, but more and more supported by nationals. Many digital infrastructures have been built in the country since 2000, and more will be built in the coming years. The country needs native high-qualified employees capable of innovating but also implementing these innovations, ensuring their operation, maintenance, and security. For example, in the area of cybersecurity, the government is aware that much remains to be done. Administrations and companies are increasingly facing cyber-attacks and must be able to defend themselves quickly and effectively. This requires highly trained engineers and technicians, who must not only have good theoretical knowledge but also be familiar with real and concrete situations and issues.

The Pro-Skima project was initiated in this local economic, technical, and academic context. It is funded by the Qatar National Research Foundation (QNRF) and managed by Qatar University/College of Engineering, in collaboration with the Institute of Technology of Lumière University based in Lyon (France). It started in March 2015 and will end in March 2019. Its general objective is to propose a new industry-integrated learning approach for graduate programs, in order to provide graduates with knowledge, skills, and attitudes that are more suited for the needs of local employers (in particular in the field of cybersecurity). Pro-Skima project is original in the sense that it is based both on (1) a collaboration between academics in the field of Social and Human Sciences (sociology of curriculum) and Computer Science and (2) a close cooperation between academics and several representatives from industry IT fields. The purpose of this chapter is both to explain the process followed to achieve such an approach and to present the main features of this curriculum proposal.

In the two first sections, we explain the theoretical framework and the methodological approach that we used to analyze an existing computing master curriculum at QU. We wanted to start with a sociological analysis because we consider that any curriculum results of an historical and social construction strongly rooted in a certain political, institutional, and cultural context. Any educational innovation attempt (especially if it is based on a transfer of some foreign curriculum models like in our case) not considering this strong social rooting would entail great risks of irrelevant proposals. In the third section, we present the analysis performed with this theoretical and methodological approach. Finally, we propose an alternative version of the curriculum, based on a work-integrated learning approach.

Theoretical Framework

Our theoretical framework is based on the sociology of curriculum developed by Bernstein and some other social scientists after him (Bernstein 1996; Luckett 2009; Stavrou 2009). This framework considers curricula as social constructions, resulting from power relations between social agents, groups, and institutions. A curriculum refers to everything that is supposed to be taught, learned, and assessed in a given order and progression (Forquin 2008). As Stavrou states: "a curriculum is an educational path implying choices within a specific educational system and within a specific socio-historical context" (2009, p. 22). Thus, it is necessary for us to identify who are the different social agents, groups, and institutions who play a role in making these choices and to understand their actions within the Qatari higher education system and more precisely in Qatar University. Two versions of a curriculum can be distinguished. The formal or official curriculum refers to what is planned by the educational institution. It is generally formalized through texts like program structure, course offering, study plan, etc. The real curriculum corresponds to what is really done, i.e., the concrete learning situations that teachers and students live. Due to multiple reason (teachers' interpretation of official texts, students' difficulties, etc.), there are always differences (sometimes very big) between these two versions of the curriculum. In this chapter, our analysis is focused on the official version of the curriculum.

In addition to *curriculum*, we also use the concepts of *classification* and *frame*. These two notions are based on the concepts of power and control, which both organize, at various levels of education systems, the discourses, and pedagogical practices of the different actors of these systems.

Relations of power pass through *classification* operations of both knowledge and actors, creating more or less strong boundaries between different social entities, their respective practices, and associated knowledge and skills. Generally, the more power a social entity has in relation to others, the more it has developed specific knowledge and pedagogical practices to transmit them. These specificities allow to develop strong identities and borders and relative self-sufficiency with regard to other entities. In this case, classification is strong. In our case, we are especially interested in the relationships and boundaries between the academic institution (Computer Science and Engineering Department of QU) who built and manage the MSc in Computing and various local employers (from SMEs to big-sized firms) in the IT field. Is classification strong or weak between these two types of institution? In other words, does the curriculum focus only on academic knowledge and require academic habits, or does it also include knowledge and skills that are used in the workplace? And do academics and professional from companies collaborate on a pedagogical plan or exist in isolation to each other, without any contact?

Control is carried out by more or less *framing* the modalities and communication rules of knowledge. In particular, framing refers to the pedagogical practices, first prescribed by different institutions (e.g., external agencies, internal pedagogical commissions) and then implemented in the different teaching situations by the teachers themselves (Stavrou 2017). These practices can lead to strong control over how knowledge is selected and then transmitted, leaving few degrees of liberty: first to teaching staff, in case of very precise pedagogical prescriptions in teaching programs, and second to learners, when their teacher leaves them little autonomy during learning situations (e.g., a lecture). Conversely, when framing (in the teaching programs) is weaker, teachers have more possibilities to develop their own pedagogy. They can decide, for instance, to set up learning activities which allows students to have greater autonomy.

In order to analyze the curriculum-building process, we also use the concept of *recontextualization*. Stavrou (2009) defines it as an activity (or set of activities) of selection and organization of knowledge and educational practices. This activity generally results in the construction of specific educational texts which are supposed to guide and orient the actions of the pedagogical actors (teachers, trainers, etc.). In our study, it is important to analyze and understand these set of activities as they exist at this university, in order to be better able, subsequently (within the Pro-Skima project), to propose adaptations of the master's curriculum. The purpose of these adaptations is to better prepare students for jobs in the local labor market in the IT field, particularly in the subfield of cybersecurity. Hence, the recontextualization characterizes the whole process of curriculum production. This process involves different actors, belonging to several institutions (e.g., teachers from a specific academic department; staff from the office of academic affairs; experts from external accreditation agencies; etc.). During curriculum creation or change, they interact with each other in different places and at different times, sometimes in a conflict way. Conflicts can arise because actors do not defend the same interests and have not the same goals, constraints, and problems. For instance, teachers in specific theoretical subjects can be very dissatisfied with the proposition from the head of the department to reduce the number of hours of their disciplines, in order to give a longer duration to an internship period. They can consider these types of theoretical knowledge absolutely essential for students to succeed both at university and in the workplace. Consequently, some can fight against this possibility, by using more or less official ways. Additionally, recontextualization generally leads to use and produce different types of written documents (minutes of meeting, reports, syllabus, study plan, etc.). Draft versions of these documents are especially interesting in a sociological perspective, because they give traces of issues, agreements, or conflicts at different steps of the recontextualization process.

Figure 10.1 synthetizes the main features of our theoretical approach.

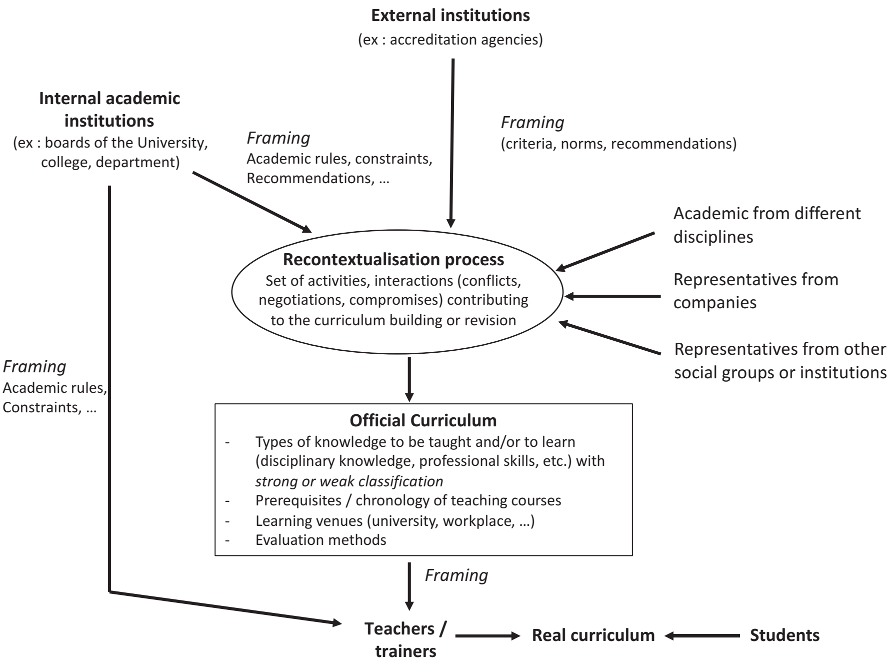

Fig. 10.1 Recontextualization process

Methodology

Our methodological approach is interdisciplinary and collaborative (see Fig. 10.2 for an overview of this methodology). As mentioned above, it involves several disciplinary fields (Computer Science, Sociology, Didactics) and types of actors (academics, professionals, etc.) who collaborate (1) to produce analyses about the curriculum organization and its recontextualization process and (2) to think about adaptations and to implement them in the curriculum. This research methodology can be defined with Lefrançois (1997) as a multifunctional scientific investigation involving close cooperation between those working in the field of research and managers and beneficiaries. As quoted by an increasing number of researchers in education (Desgagné 1997; Donovan et al. 2013), collaboration of researchers and practitioners is essential in order to develop a progressive and common understanding of a complex set of social practices and organizations (university and companies). This shared understanding is also a key point for transforming and getting closer these different worlds of practices.

> The traditional relationship between researcher, the producer of knowledge, and practitioner, the user of knowledge, was replaced by a commitment to the notion of two sources of knowledge (research and practice). Though the two sources might generate somewhat different types of knowledge, both types are judged to be of equal value and importance to improving educational outcomes. (Snow 2015, p. 461)

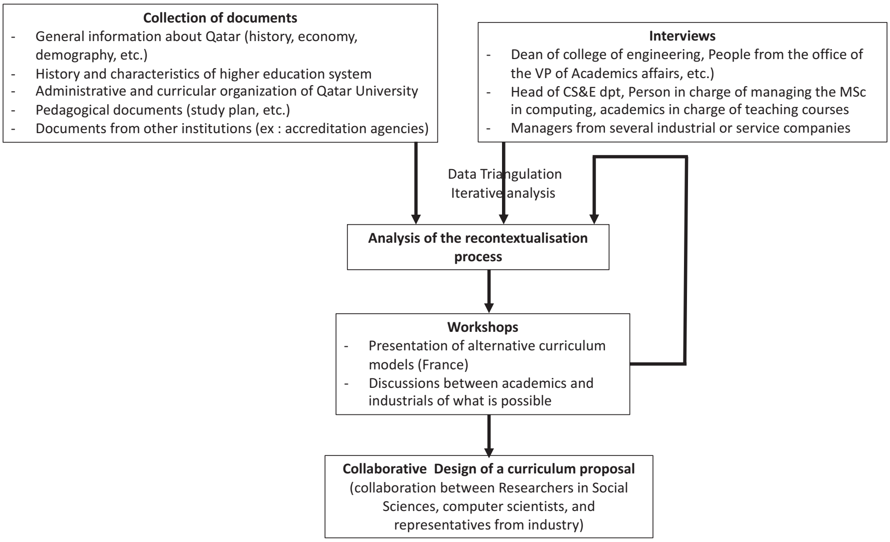

Fig. 10.2 Schematic view of the methodological approach

In order to analyze the current curriculum, we have built a corpus made of three types of data. First, we have collected various written documents about (1) the general history, economy, demography, sociology, and culture of Qatar; (2) the history and characteristics of its education system, especially at tertiary level; and (3) the administrative and curricular organization of Qatar University. Second, we have conducted interviews with different types of actors: they were carried out in focus groups or individual during the first 2 years of the project. These people were administrators, teachers, but also representatives of several industrial or service companies. We transcribed these interviews and then used a thematic content analysis. In addition, we collected feedbacks during two workshops at Qatar University (of 2 days each, within a 1-year interval). These workshops were organized between academics and professionals to present other ways of organizing a graduate curriculum in the field of IT and particularly in computing. These observations brought us important information to complete our analysis of the recontextualization process. We have studied these three types of data by mobilizing an iterative and triangulation method.

This sociological analysis allowed us to identify the main characteristics of the curriculum and to better understand what is possible to change in a realistic way, given the existing social constraints. We also drew inspiration from two pedagogical models existing in France that we tried to adapt to the Qatari economic, institutional, and cultural context. This proposal was presented to both pedagogical staff of the MSc in Computing at Qatar University and industry representatives during the last workshop (already mentioned above). After hearing both academics and professionals, it was clear that some curriculum models are hardly transferable in Qatar, given local realities and constraints of both the university and the labor market. The discussions and feedback made it possible to refine the proposal to make it as realistic as possible.

Analysis of the Curriculum and Its Recontextualization Process

Teaching Contents and Pedagogy

According to several documents of the mentioned MSc program taken as example for our study (website page, pedagogical report, etc.), the training program "aims at preparing highly skilled well-qualified computing professionals who can meet the demand of corporate Qatar and contribute to the national growth and development."[2] Looking more precisely at the curriculum organization and the pedagogical approaches, such objective related to the preparation of future professionals seems not so obvious.

The current study plan states that three core compulsory courses must be completed by all the students who attend the MSc in Computing: algorithm design and modeling, applied research methodology, and seminar in computing. In addition, they can specialize in two different fields (*Computer Science* or *Computer Engineering*) by selecting four "focus area elective courses" in one of these two focus areas. At the beginning of the second year, they have also to choose between two options: either a research-oriented "thesis" option or a practical "project" option. In the first case, they carry out a more academic and theoretical study, which can be the first step before a PhD work, while in the second, the project focuses on an applied project, ideally based on some industry issues and related data.

If all the teaching courses are intended to be "applied" and not just theoretical, interviews we had with teachers show that topics and applications proposed are still closely linked to academic issues. Teachers make little reference to workplace situations, and if some do so, a strong link with industry stakeholders is not clearly mentioned. Such link is indeed important, as studies on the professional expertise show that experts' knowledge and skills are not only technical but also organizational, communicational, relational, event-driven, and managerial (Visser and Falzon 1992; Bereiter and Scardamalia 1993; Eraut 2007; Tynjälä 2009). Their competencies are made of these different knowledge, skills, and attitudes, which are strongly interlinked to deal with complex professional situations. Experts cannot develop these types of competencies only through academic or scholar situations but need to have sufficient workplace experience to be able to do so.

At the bachelor level, students also have few opportunities to do internships during their training program. One is possible at the end of the first year of the curriculum (during the summer period), but the lack of contacts with local companies and the overloaded schedules of teachers hinder their implementation in an efficient way, which is not the best way to familiarize students with corporate issues. We might think that the master students who choose the project option have more opportunities to develop vocational knowledge, skills, and attitudes. Initially, the pedagogical team of the master thought that these projects could be ordered by some companies. In reality, this is rarely the case. Most of the time, students' projects are proposed by faculty, in connection with research issues in their teams.

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[2] http://www.qu.edu.qa/engineering/academics/computer/ms

In sum, the curriculum of the MSc in Computing offers few opportunities to gain practical experience in the workplace. Most of the teachers seem to consider these practicum periods as not really important. Priority is to acquire disciplinary knowledge and to develop academic skills and attitudes. Our hypothesis is that many think that professional knowledge is more or less an application of theory (Schön 1987). But generally faculty's attitudes can also be explained by their own agenda, preoccupations, and constraints, which are much more oriented toward academic issues than local companies' needs. In addition, some academics are probably unfamiliar with the industrial world and can fear or do not know how to develop educational collaborations with professionals. Within Bernstein's theoretical approach, it means that knowledge taught in the master program is in a strong classification with regard to knowledge used in the professional spheres. Boundaries remain very important between these two social spheres. As in many universities, knowledge and pedagogical practices at QU remain strongly influenced by the academic culture, far away from learning through experience at work. The two types of knowledge and pedagogical practices do not mix. More generally, the academic institution seems to keep a strong power over the definition of the curriculum of the master degrees in IT, without involving much employers in their design or update, whereas this training program is supposed to prepare skilled people for them. Interviews with several representatives of IT firms confirm they are not familiar with the content of the training program and have rarely been asked to contribute actively to the curriculum updates (only sometimes to give their general opinion about what exists via questionnaires).

In the case of QU, a lot of the students who attend the MSc in Computing are professionals.[3] We might think that this is a great opportunity to facilitate the connection and collaborations between the university and companies that employ them. Of course, this is not a straightforward action, as in most cases, these students who decided to go back to the university after several years of work did it alone, without informing their employers. It seems also that the local education culture does not encourage students to ask teachers to make more links with professional issues. They remain very passive during teaching courses.

Curriculum Revision Process

In Qatar University, any curriculum creation or modification must follow a precise and formalized circuit. When the curriculum of the MSc in Computing has been modified in 2016, three bodies, located at three levels of the university organization, were involved: the Computer Science and Engineering Department; the College of Engineering (including the CSE department); and the Vice-Presidency for Academic Affairs which tackles the various colleges. This process was initiated by

[3] For this reason, classes are scheduled in the evening (5 pm–8 pm) to allow these professionals to attend the different courses, after their working day.

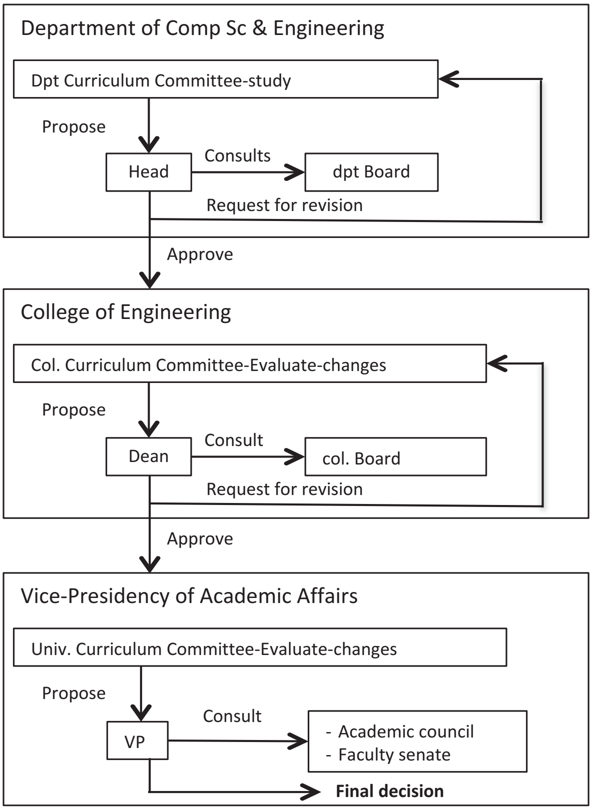

Fig. 10.3 Diagram of the process of curriculum validation in QU

a department curriculum committee-study, composed of several academics. Before making a written proposal, they consulted their colleagues and students through various means (meetings, surveys, etc.). A panel of employers[4] (governmental and private organizations) was also consulted via a written questionnaire. Afterward, the process followed the detailed circuit below (see Fig. 10.3).

This diagram highlights three levels of validation that may occur long and complex decision process. Several back-and-forth interactions between these levels are in general made before a final agreement could be found.

A first explanation of this long process lies in the interdependencies between the different training programs of QU. First, curricula must respect a common general structure (two semesters, fall and spring, with a total of 16 teaching weeks). Courses must be accounted for in credit hours (CHs), with a minimum number of CHs to validate a course. For a master, the minimum is 30 CHs of both compulsory (required) courses and optional (elective) courses. In the case of the MSc in

[4] This consultation was intended solely to collect their satisfaction with the training program, not to involve them in any modification of the curriculum.

Computing, some of these elective courses are not specific to this training program: students who choose them can be grouped with students from another master of the College of Engineering. For instance, *applied research methodology* is a common transversal course for students from two master programs of the College of Engineering (MSc in Computing and MSc in Electrical Engineering).

This makes any process of curriculum revision complex on different dimensions: administrative (availability of professors, interest and demand for a given course), pedagogical (avoiding students with too heterogeneous levels in a course), and financial (limiting the number of open courses among all those that exist). Any modification of a curriculum can have consequences on several others. It is therefore not surprising that the university seeks to secure the approval of several actors and bodies at different levels of the organization before agreeing to a modification of a curriculum.

But there are not only internal norms and procedures imposed by Qatar University. Other external institutions have an influence on the organization of the curriculum. The teaching contents and the pedagogical situations are strongly based on international standards in a competitive logic both in the Gulf region and in the globalized academic world. Interviews reveals that the designers of the master program were strongly inspired by existing master curricula in the IT field in what they consider to be the best universities in the world, essentially in North America. The North American influence is reinforced by the choice of the university to use the US ABET accreditation agency for its bachelor programs (College of Engineering, particularly). This choice is part of the general strategy of QU to ask as much as possible this type of accreditation for all training courses (especially bachelor, but for some years also master programs). QU selected agencies that are most recognized in each academic specialty. Most of these agencies are Northern American (US, Canada) ones. QU legitimizes this choice of external accreditation by the aim of reaching international quality standards. Other universities within the Gulf area (Saudi Arabia, United Arab Emirates, etc.) have made a similar choice. It is important for QU to gain similar accreditations to compete in this regional academic market. As a sign of the institutional importance of this type of accreditation, we can find (in May 2017) "proud to be accredited" on the first page of the website of the College of Engineering.

The initial objective of the CSE department staff was to also formally obtain this accreditation for the MSc in Computing. But they finally decided not to do so for lack of time. Nevertheless, they have made extensive use of the ABET criteria to develop the new version of the curriculum. One of these criteria is the necessity to generate 11 learning outcomes. For instance, each graduate student has to develop "an ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs" or "an ability to analyze the local and global impact of computing on individuals, organizations, and society." In addition to these outcomes, ABET also asks for necessary inputs, i.e., specific teaching contents, which have to be implemented within the curriculum. For instance, "Students must have the following amounts of course work or equivalent educational experience: a. Computer science: One and one-third years that must include:

(1) Coverage of the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and architecture; (2) An exposure to a variety of programming languages and systems." A detailed analysis of all the norms fixed by ABET is not the scope of this paper, but we can observe that using these criteria lead to a normalisation process, controlled by an external institution to QU. In particular, the eleven learning outcomes define a generic profile of what must be a student in computer science and computer engineering, whatever higher education institution and its cultural, political and socio-economic environment.

Finally, we have shown that several internal and external institutions have a very important influence on any evolution of the curriculum. In Bernstein's theory, it means that framing from these institutions is strong and greatly reduces the possibilities for the pedagogical staff to modify the teaching contents and the pedagogical approach. In particular, there is little space to discuss more flexibly with local employers and to make some rapid changes in the teaching contents in order to answer to their competency needs. This is particularly problematic in the case of rapidly changing professional practices. For instance, learning to be an expert in cybersecurity requires to be closely and strongly connected to rapid evolutions in the real world.

Proposal of a New Industry-Based Curriculum

Despite strong social constraints revealed by our sociological analysis, we think there is space for an interesting change that does not affect existing courses and the complex interdependencies between each component but that makes better links with the industry and marketplace.

To build such proposal, we took our inspiration from two pedagogical models existing in higher education in France that we adapted to the local context of Qatar University: one from IUT Lumière (University of Lyon, France) and another one from some graduate schools in the field of industrial engineering (Institutes of Industrial Engineering Technics (ITII)). We begin by presenting the organizing principles of these two curricula, before outlining the proposed changes to the MSc in Computing.

Pedagogical Model of Lumière University Institute of Technology (IUT)

University Institutes of Technologies were created in the 1960s in France, in strong after-war economic development context. At this time, French industry was still dominated by Taylorism, with a large number of nonqualified workers. The service field was not very important, and administrative organizations remained traditional in their organization, with plenty of low-qualified people. But important further evolutions (development of machine tools, automation, computerization, more and more complex administrative tasks, quality approaches, etc.) have generated new skill needs, which are difficult, if not impossible, to learn only on the job. Employers needed not only more engineers or industry and service executives but also middle-level managers and advanced technicians to make the link between executive and low-skilled workers.[5] Since that time, many IUT have been established throughout the country to train these advanced technicians and middle-level managers in several industrial specialties or services.[6] All curricula are built in collaboration with employer representatives at national level and emphasize technical training in order to better meet employers' needs.

However, professionalization has long remained a weakness in this type of technical institute, with students having only a few weeks of internship during the curriculum. Employers often consider this as a problem, because students lack professional experience when they hire them. As a result, they had to take extra time to make them operational for the workplace. The Lumière University Institute of Technology (IUT Lumière) was founded in the early 1990s, with the aim of training middle-level managers and advanced technicians with more attention to this issue.[7] Initiators of this Institute chose to organize all the training programs in a *cooperative education* way, meaning that all curricula combine university training and supervised workplace learning phases within the same company (cf. Fig. 10.4). This pedagogical approach allows students to acquire general, technical, and scientific knowledge and at the same time to build professional skills in the workplace. This pedagogical alternation between two learning venues (university and workplace) does not start from the beginning of the training program. During the first year, students are prepared for the workplace because many of them never had any professional experience before.

To do so, additional sessions to traditional courses are scheduled during this first year in order to make progress on the following points:

- Their personal and professional project. What job of function do they want to carry out? In what type of company (small, large, industry or service, etc.) do they want to work? What level of responsibility (executor, middle-level manager, manager) do they want to have? How will this future professional position be related to their personal and family life? The underlying assumption is the more a student's project is clear, the better his/her chance of success is (more motivation, in particular).

[5] Another more social objective was to promote access to higher education for young people in the working classes.

[6] 24 types of training programs, e.g., legal career, marketing methods, administrative management of companies and organizations, chemistry, mechanical and production engineering.

[7] This technical institute offers 2-year or 3-year training programs in different fields: administrative management of companies; logistics and transport, quality, and production management; risk, safety, and environmental management; and statistics and business intelligence.

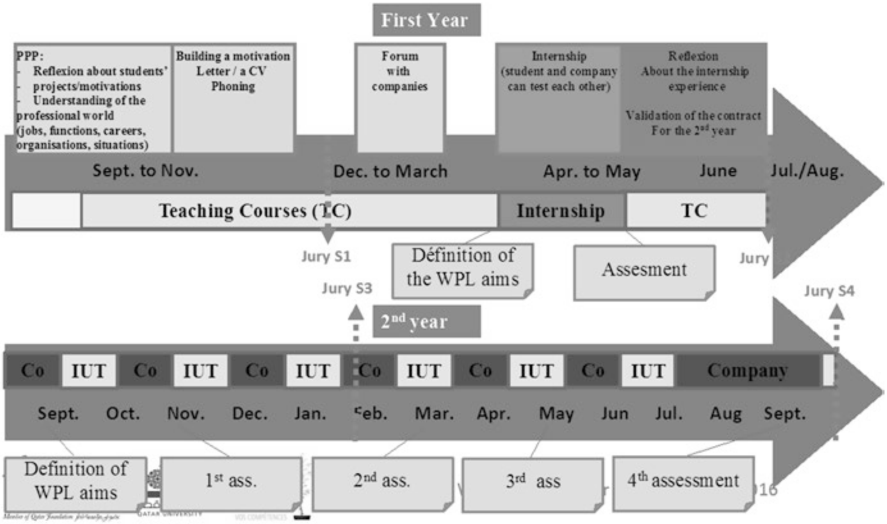

Fig. 10.4 Curriculum of training programs at Lumière University Institute of Technology

- Knowledge, skills, and attitudes expected by companies. Workplaces are not only technical but also social environments, with hierarchical relationships, ways of interacting with peers, etc. When employers take a trainee, some complain about their behavior (delays, inappropriate outfit or communication style, etc.). This a way to avoid these problems.
- Their ability to learn how to learn in the workplace. Many research studies show that workplace learning is largely dependent on people's ability to take advantage of affordances (possibilities to participate to collective work practices) (Billett 2001; Filliettaz 2009; Veillard 2015).

Some innovative learning situations have been set up to help students progress on these different issues.

- PVP sessions (personal and vocational project). They are not traditional lectures, but very active and participative sessions for students. They allow them expressing, sharing, and questioning their representations about jobs, professional practices, companies, field of expertise, etc. They investigate on these different professional aspects through documentary researches or interviews with professional. Trainers also give them personal advices to contact employers (using databases, targeting companies, phoning, making appointments), to make a CV, to introduce themselves to a recruiter.
- A 7-week internship in a specific company. This internship is scheduled at the end of the first year. Students are integrated into a company department and start participating in simple tasks. This internship is also a reciprocal testing between the student and the company. If everything goes well from both sides, then an internship contract is signed for the second year.

During the second year, students regularly switch between training phases at university (lectures, practical works, collective projects, etc.) and workplace learning periods in the company. The rhythm of alternation can be different according to the training program: either 3 days in a company/2 days at the university or 15 days in a company/15 days at the university. This is a pedagogical choice depending on the characteristics of the professional tasks to be learned. If these tasks are performed daily or weekly, a weekly rhythm is more appropriate, allowing students to integrate a professional community of practice (e.g., a HR department) as whole participant. For example, in one training program about administrative management of companies, designers of this program decided to choose a weekly rhythm because lot of tasks (payroll, back office operations, etc.) occur daily. But in other training programs, students' missions often consist in carrying out small projects. A 15 days/15 days rhythm is more appropriate because the project can be stopped for 15 days without affecting the company's productivity. It is therefore important to make a temporal analysis of tasks or missions to decide.

During his/her workplace learning trajectory, each student is supervised by a professional tutor, who is an expert in the job. He/she is also helped by a university tutor (an academic contributing to the master's degree). These two tutors have complementary roles. The first one daily supervises the student in the workplace (reception and integration assistance, transmission and explanation of the tasks, support during execution, evaluation of results and behavior at work). The second is in charge of relating the academic and professional parts of the student's curriculum: explanation of the objectives and contents of the training program to the company tutor, assistance for evaluating the apprentice, etc. Several meetings between the apprentice and his/her two tutors are organized in the company during the year (4 or 5 according to the training courses). They allow successively to assess the apprentice's achievements, his/her behavior at work, and more generally what he/she has learned over a period of time; to assign tasks or goals for the next period; to discuss the topic of the dissertation that the student has to write at the end of the training program (see below); and to assess this dissertation (last meeting). A follow-up booklet, with some evaluation grids and several criteria, is used to support students' assessments. The marks obtained by the student have a significant weight in gaining the diploma (about 30%).

All along this second year, students have different courses to complete their general and technical culture. As said previously, they also have to write a dissertation on a specific professional issue at the end of the second year. This work includes the following steps: identifying a problem (organizational, technical, or human kind) that arises in their company; conducting a small study to understand its causes; looking for possible solutions; and finally making recommendations to solve the problem. Specific workshops have been set up to help students in writing their dissertation. They take place in the second half of the second year (spring semester).

Another challenge for students during this second study year is to think about the future, once they graduate. They often ask themselves many questions: is it better either to keep studying or to go to the job market? In the case of further studies, what is the best training program given the student's professional project? etc. To help them in answering these questions, so-called PVP sessions were added during the second year. They are based on similar pedagogical principles as those used during the first year: starting from students' representations and life experiences, initiating collective discussions, promoting personal inquiries, etc.

Pedagogical Model of Institutes of Industrial Engineering Technics (ITII)

Institutes of Industrial Engineering Technics (ITII) were created at the beginning of the 1990s in France to address the lack of industry executive capable of managing industrial projects or production units. In 1989, a prospective study[8] pointed a significant lack of graduate engineering, having both a good level of scientific and technical knowledge and concrete capacity to manage industrial situations, particularly in small- and medium-sized enterprises. At this time, there were many "Grandes Ecoles d'Ingénieurs" (master's degrees), but all of these curricula were very academic, favoring a high level of theoretical instruction. In particular, there were few internships during the training program studies. As a result, graduates were poorly prepared to deal with concrete problems in companies and to manage operational or project teams. This was a problem for French companies in a context of tough international competition, where competency issue was playing an increasing decisive role. The report recommended to create new types of graduate engineering programs, based on work-integrated curricula. It also recommended that students should be selected differently. Whereas traditional "Grandes Ecoles d'Ingénieurs" selected their students only from academic criteria (very good marks in mathematics, physics, technology, etc.), the idea was to recruit students who not only have good scientific and technical knowledge but also show other qualities like communication skills, practical abilities, managerial dispositions, etc.

Several ITIIs were established in France following this report. They are managed in partnership between employers' organizations and universities. Training programs are available to both students who have just obtained a bachelor's degree and employees with 5 years of professional experience. The 3-year curriculum alternates periods of teaching at the institute (3–5 weeks), with workplace learning periods (4–6 weeks) in a specific company. Figure 10.5 shows an example of this type of curriculum in a specific ITII.

In this particular institute, the teaching part includes lectures; directed works in the form of case studies, presentations, or practical works in laboratories or technological halls; tutored sessions (at least 1 per period), which are designed to help students during their workplace learning periods in a company (see below); and self-directed sessions (students working in group without teacher or tutor).

[8] Decomps report (1989) submitted to the National Ministry of Education.

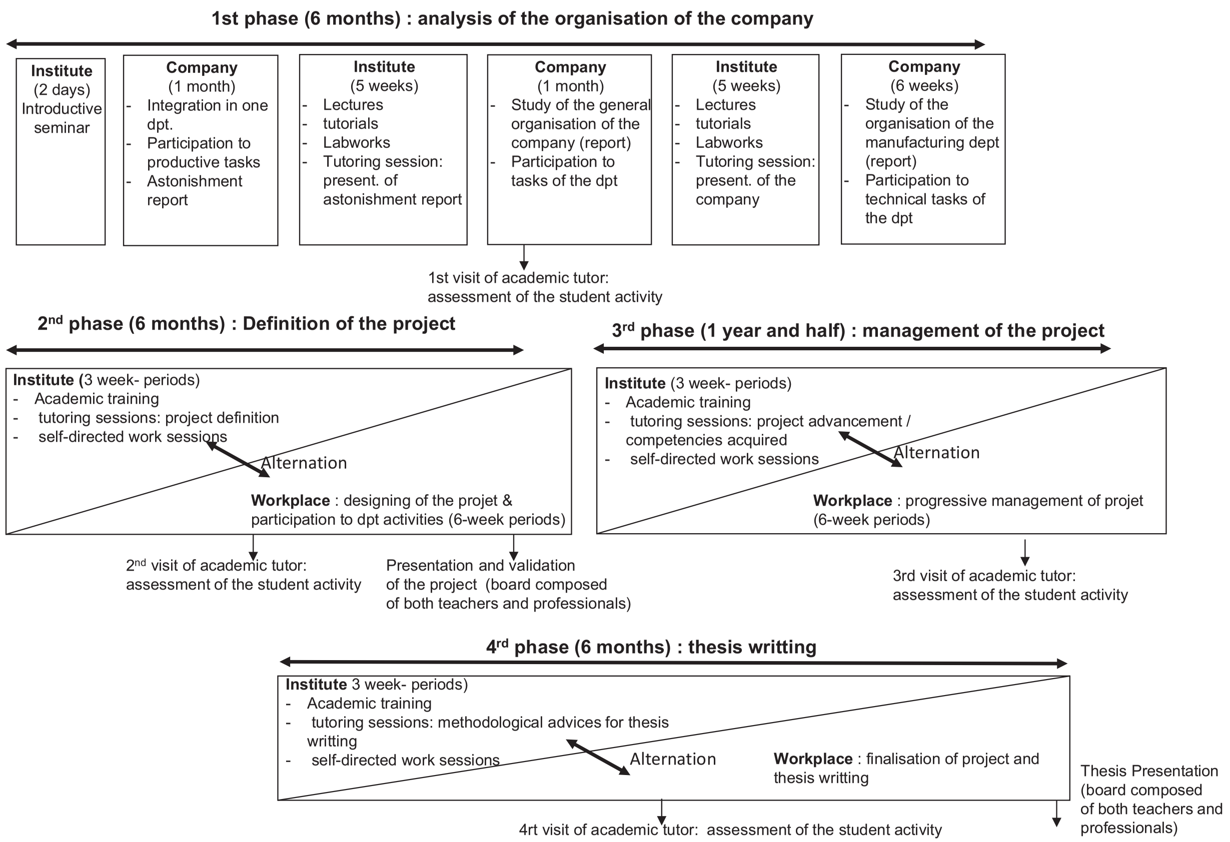

Fig. 10.5 General organization of the curriculum in one ITII

In the workplace, each trainee is supervised by a company tutor, usually the manager of the department. Each of them is also supervised by an academic tutor, who is a teacher of the institute and knows the technical field. These academic tutors travel several times to visit their trainees in their company (see below). But they also managed the tutored sessions mentioned above. During these sessions, they bring together their trainees in order to help them, both a methodological and technical plan, to carry out their project in their respective company. But the finality is also to make them think collectively about situations they experienced at work (what communicative, technical, managerial difficulties did they face off? How is it possible to solve them? What is possible to transfer in another professional context, etc.?).

The workplace learning trajectory is divided into four phases.

- A first phase (6 months) where students discover the organization of their company and integrate into a specific department (e.g., methods office, engineering department, manufacturing department, etc.) by participating progressively in the collective activity of this department. They have to write three small reports: an astonishment report (first period); then a report which presents the general organization of the company (second period); and, finally, a report which analyzes in more detail the manufacturing process of the company, trying to point out its strengths and weaknesses. Upstream, the academic tutor gives instructions to guide the preparation of these reports. Then, students present their work during tutored sessions at the institute.
- During a second phase (6 months), trainees are supposed to build a project to improve the industrial organization of a part of the company (e.g., improving the quality of the manufactured products, reorganizing a manufacturing process, etc.). The design process of this project is progressive and must be done in agreement between the student, the company tutor, and the academic tutor. Students are helped on a methodological plan by their two tutors. At the end of this phase, they present their project toward a jury composed of both teachers of the technical field and professional experts. This jury validates the project by paying attention to its quality, profitability, and progressive learning potential.
- During a third phase (1.5 years), students carry out their project in the company, under the supervision of their company tutor. They regularly present the project progression to their academic tutor and other students, during tutored sessions at the institute. These sessions allow them to have methodological or technical advices to manage their project but also to reflect on the skills that they acquired their transferability in other work situations.
- The fourth and final phase is devoted to the finalization of the project and the drafting of the final thesis. This thesis consists of a detailed presentation of the project (objectives, challenges, methodology, organization of the project team, tools and resources used, results, feedback on experience) to a jury composed of both teachers and professional experts.

Each academic tutor visits his or her students in their company four times: twice during the first year, first to ensure that the student is well integrated into the company and then to exchange with both the company tutor and the student on what can be the project; one time during the second year; and another time in the middle of the third year. Each visit involves an evaluation of the student. Evaluation grids are used. They are based on several criteria like technical knowledge acquired, understanding of the organization, gain of autonomy in the work, development of communication and managerial skills, etc. Tutors are particularly aware of the students' learning progress concerning management issues, insofar as the objective is to train future industrial production managers.

Proposal for a New Type of the MSc in Computing

To make this proposal, we took our inspiration from the two models of curriculum presented above. This curriculum proposal concerns only the "project" option of the MSc in Computing. The "thesis" option is not concerned insofar as its purpose is to train students for academic research and not for immediate occupations or functions in companies. Figures 10.6 and 10.7 present the main features of this new curriculum.

We have considered two strong constraints that emerged from the sociological analysis. The first is that it is not possible to change the current schedule of the teaching courses (5 pm–8 pm), as many students are salaried and work in the morning and early afternoon in their company or administration. A second constraint is that existing courses cannot be changed or added for the reasons discussed above (complexity and length of the course revision process, interdependencies with other courses delivered by other department or colleges, international criteria to respect). But despite these constraints, it is nonetheless possible to improve and enrich the "project" module, planned in the current curriculum in the spring semester of the second year.

We propose to come back to the initial idea of the master program designers, which planned that all the projects carried out by the students should come from an application or order from a company. We suggest taking up this idea by going further. What has been set up in ITIIs in France can serve as a model. In the new curriculum, each student will carry out a project for a company, at the same time as he/she will follow the teaching courses of the master program. The curriculum will therefore be organized in a "cooperative education" way (Bouras et al. 2014), that is, students alternate between two learning venues: university and workplace. Two scenarios are possible depending on the student profile. Either he/she is a person already employed by a company, who resuming university studies. This presupposes that company has IT needs and there is an IT department or function that can support the student in carrying out his or her IT project. Either he/she is a young undergraduate student who is continuing his/her studies. In this second case, a company must be interested in hiring him/her as an employee or take him/her as an intern for the duration of the master (2 years) and can entrust him/her with an IT project.

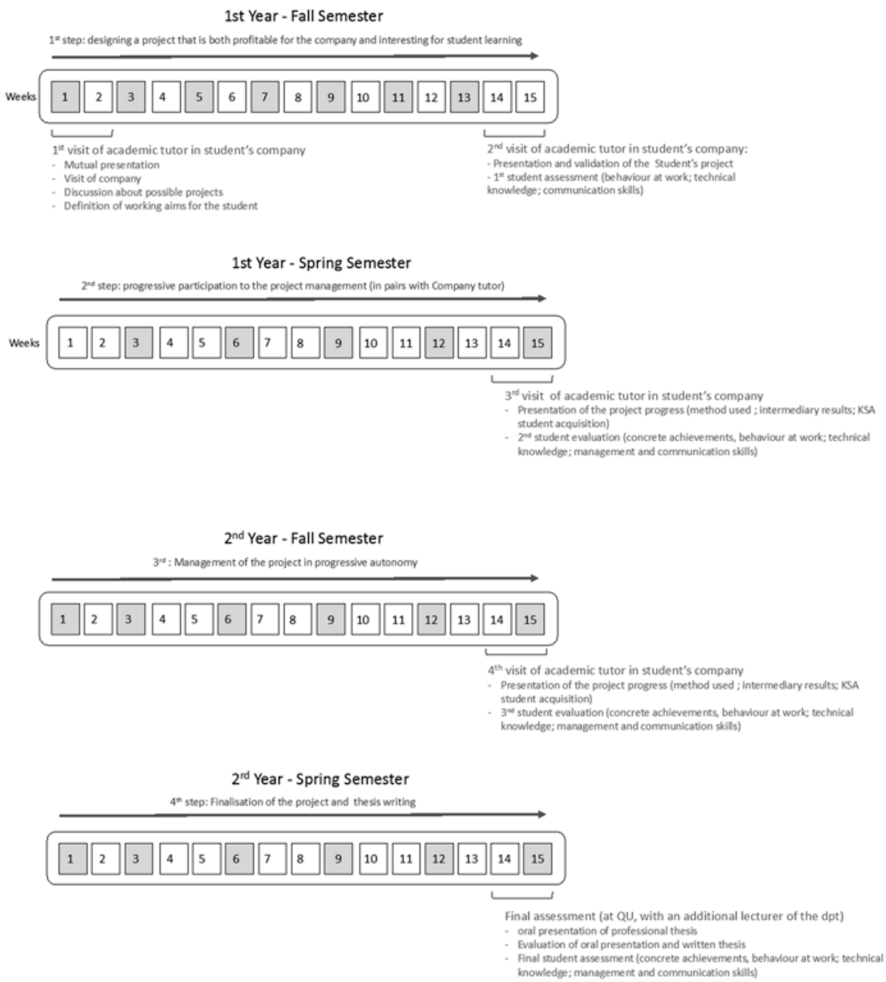

Fig. 10.6 Semester organization of the curriculum proposal

In any case, our proposal requires a closer collaboration between the Computer Sciences and Engineering Department of QU and local partner companies, in order to negotiate projects that both meet real corporate needs and are interesting for student learning. It also requires a reinforced dialogue between the student, his/her company, and the teachers of the MSc in Computing, so that the first one chooses optional courses that are as coherent as possible with the project he/she carries out in the company.

In addition to existing courses, our proposal is to add support and coaching sessions to help students on three points: (1) definition and steering of the project to be carried out in the company; (2) development of their personal and professional project; and (3) writing their professional thesis at the end of the master program.

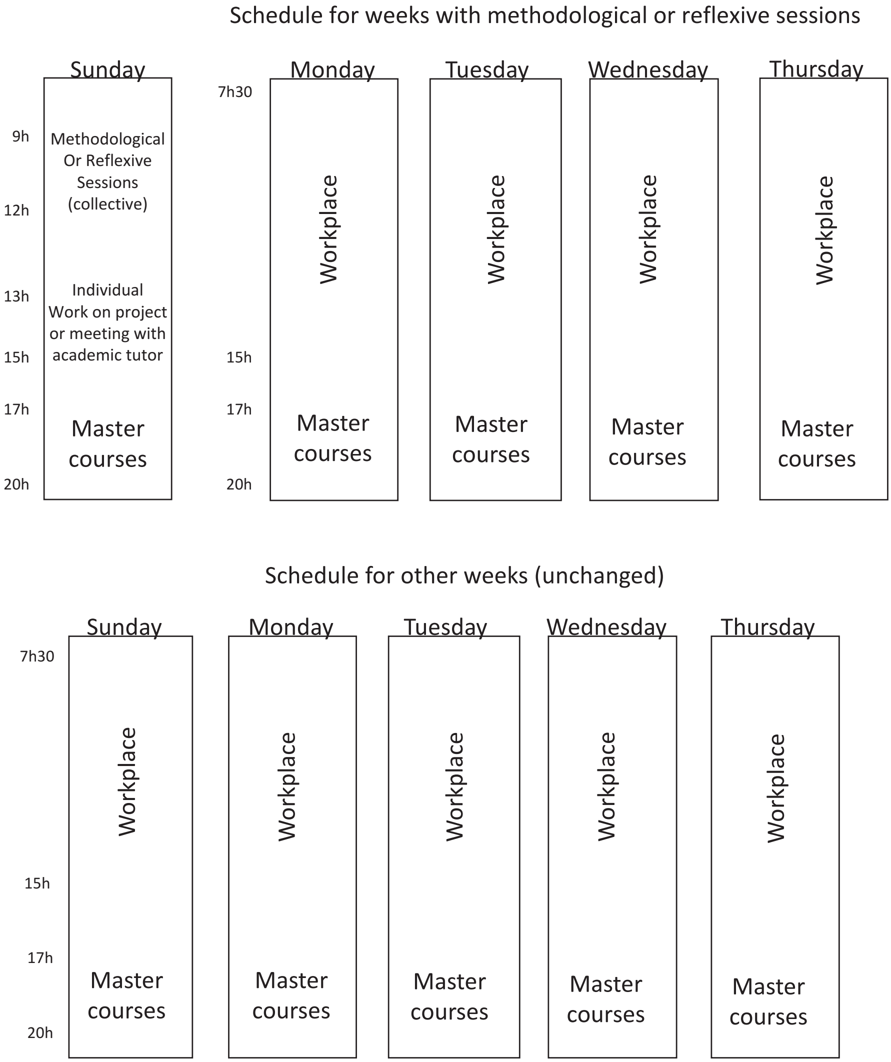

Fig. 10.7 Organization of the week

These sessions are not additional courses but methodological assistance (project, dissertation) or reflexive phase about students' workplace experiences. They take place on Sunday morning (9 am–12 pm) at the University. This means that companies must agree to release their student-employee (or student-trainee) for 1 day during certain weeks so that they can attend these sessions (cf. Annex 2). Students have time during the afternoon (1 pm–3 pm) to individually deepen collective reflections done in the morning. These 2-hour time windows in the afternoon can also be used to meet the academic tutor and discuss about work in the company. These sessions take place about every 15 days during the fall semester of the first year and then every 3 weeks during the following semesters (colored in gray in Annex 1). During weeks with no session, students alternate between tasks in their company (morning and early afternoon) and lessons at QU between 5 pm and 8 pm.

The first type of session (project methodological assistance) has several objectives. First, students must learn basic concepts and tools for project management in the IT field. It is also a question of advising and helping them during the building phase of their project, which will take place during the fall semester of the 1st year. Indeed, this first phase is particularly complex, as it will require not only a technical reflection with new concepts and tools but also an analysis of the company's needs, in line with its information system strategy. This also often requires negotiations with different actors of the company to convince them to commit themselves to such a project and to finance it. Thereafter, assistance will be provided to students for technical, financial, and human management of the project. During these sessions, students regularly present the progress of their project to the group. We propose to position several sessions during fall semester of the first year (six sessions over a period of 15 weeks). At that first step, students need help to assimilate project concepts and tools and implement them into their own IT project for their company. In spring semester, there are two sessions (midterm and end of semester) allowing students to present the progress of their project, through a project review. The teacher in charge of these sessions must facilitate exchanges of experiences between students and provide individualized methodological advices.[9] During the second year, three additional sessions will be held (two during fall semester and one at the end of spring semester), again to present the progress of projects and advise students on the management part of these projects.

The second type of session is workshops to help students in writing their thesis. Indeed, writing a professional thesis is a very difficult exercise for many students, even at the master's level. Moreover, in such a new curriculum, this professional thesis will not only be read by academics but also by people from the company where the student does his/her internship. It is therefore twice important that this written document be of good quality, both in substance and form. The aim of this professional thesis is to give a detailed account of how student has solved an IT problem or answer to an IT of his/her company, by using theoretical knowledge and methodological and practical skills. It must be a high-level reflection in response to this problem or need (but also involving organizational, financial, and human dimensions) that arises in the company. This professional thesis work is orally defended at QU, at the end of the second year, toward a mix board composed of the two tutors of the student (academic and professional), plus another academic who does not know what was going on with the student in the workplace. People in charge of managing these workshops have to work closely with both students' academic and professional tutors, so that the methodological advice provided is consistent with the recommendations made by the two tutors regarding the choice of the problem and a plan.

[9] Ideally, the facilitator of these sessions will be an experienced teacher in IT project management, with good knowledge of the needs and problems of companies in this field.

The third type of session aims at providing students with resources so that they can make the best possible career choices. Indeed, in an increasingly complex and globalized world, it is not often easy to make personal choices about the type of job you want to do, the company where you want to work, the amount of time you want to spend with your family, and so on. The term "personal" is also used because important professional choices are not without consequences for personal life and vice versa. These choices arise first during university studies, then immediately after, and again at certain more important points in his/her professional career. During these sessions (three in spring semester, year 1; one in fall semester; and two in spring semester, year 2), students can explore, for instance, the following two sets of issues: a first one around their educational choices in relation to their professional and personal project (e.g., Why did they choose this particular master program? How can this educational choice help them to realize their personal and professional project? etc.) and a second one about what they have learned and how these acquisitions can be transferred in other situations. Managing this type of session requires probably to be familiar with the cultural context of both Qatar and its neighboring countries in the Gulf region and to have a good knowledge of the regional job market.

As said previously, each student is attached to one company during the master program. We suggest that the student, the company, and QU sign a symbolic contract to formalize their mutual commitment in this work-integrated training program. This document can stipulate the duties and responsibilities of each part.

- Company: facilitating student's integration into a specific department; allowing him/her to participate to the collective activity of this department; supporting him/her during workplace learning, especially by naming a company tutor who will be in charge of managing him/her; releasing the student to attend courses and supporting sessions at QU; etc.
- CSE department: appointing an academic tutor for each student of this program, supporting students during the project definition and management, helping them to transfer theoretical learning to their project, etc.
- Student: being present and attending courses at QU, respecting the companies' schedules, not disclosing confidential information to other students or academics, etc.

Each student is followed up by two tutors: a professional tutor from the company and an academic tutor (lecturer) from the Computer Science and Engineering Department of QU. Several meetings bringing together the student and his/her two tutors will be organized inside the company, both to fix student's missions and assess his/her achievements and behavior at work. We suggest five meetings during the 2-year master program (see Annex 1).

- A first one, at the very beginning of the master course (fall semester, first year). Content: mutual presentation; visit of company; first discussion between the student and the two tutors about possible projects; definition of other student tasks

- A second one, at the end of this first semester. Content: presentation and validation of the student's project; 1st student assessment (behavior at work; technical knowledge; communication skills)
- A third, at the end of the spring semester of 1st year. Content: presentation of the project progress (aims, tools, and methods used, achieved tasks, intermediary results); student assessment (concrete achievements; behavior at work; technical knowledge; management and communication skills)
- A fourth, at the end of the fall semester of 2nd year. Content: presentation of the project progress; student evaluation (same criteria)
- A final one, at the end of the spring semester. Content: final presentation of the project (aims, tools, and methods used; achieved tasks; final results; perspectives; project review); final student assessment (same criteria)

It is better that only the company tutor evaluates the student, because he/she is the one who knows the best what the concrete students' achievements and behavior at work are. The university tutor's role is to facilitate the evaluation process, especially by explaining the evaluation. An assessment booklet is required for (1) fixing the respective roles of the two tutors; (2) writing the objectives and tasks assigned to the student; (3) guiding student's evaluation according to precise criteria; and (4) keeping a written record of all the results of this assessment process and communicating them to the CSE department. This booklet can be paper or digital. A digital and online version can accelerate and facilitate the circulation of the documents between the different actors of the training and make them more reliable. However, this can be problematic if there is a computer network failure.

Conclusion

This proposal for a new curriculum, even if it does not change the formal framework of the master program, requires an important change in the practices of the academics who will implement it. They will no longer only be teachers and researchers but at the same time tutors. The new curriculum is also an important novelty for a university that has so far remained very academic and does not usually have a strong collaboration with private companies. For these reasons, we recommend a gradual implementation. For instance, a first experiment could be done with a small group of volunteer students and some companies in the IT sector who are particularly interested in testing this new type of work-integrated curriculum. It is also necessary to be able to rely on a team of few motivated academics of the CSE department to manage the supporting sessions and play the role of university tutors.

Moreover, it will be probably difficult to set up from the outset an organization of the project over the 2 years of the master. To begin with, the first year of the master could remain unchanged. In this case, the project in companies and the support sessions could only start from the beginning of the second year (fall semester).

Annex 1 shows what such a reduced curriculum could be. This would require first defining a project much more quickly (in 6 weeks instead of 15). To speed up the IT project building phase, we propose to put more project support sessions during the first 6 weeks of the fall semester (four sessions). Students will then present the progress of their project during three other sessions (one in week 15 of fall semester; two in weeks 6 and 12 of spring semester). Concerning the other types of session, we suggest that PVP sessions can be scheduled in weeks 1 and 9 of fall semester and in weeks 2 and 10 of spring semester. Workshops dedicated to professional thesis writing can be positioned in week 12 of fall semester and in weeks 4, 8, and 14 during spring semester. This shorter version also requires reducing the number of visits of the academic tutor in the company (Two instead of four), as well as the number of assessment of student's work in the company (three instead of five).

A first proposal based on this work is under discussion between the CSE department and few of its partner companies. It is related to a master certificate on cybersecurity with a strong involvement of the industry. Such certificate is not a degree but a certification to be provided to students in the specific field of cybersecurity after following a specific track of the master. It is expected to be implemented during this academic year and will clearly open the door for its extension to the whole master curricula.

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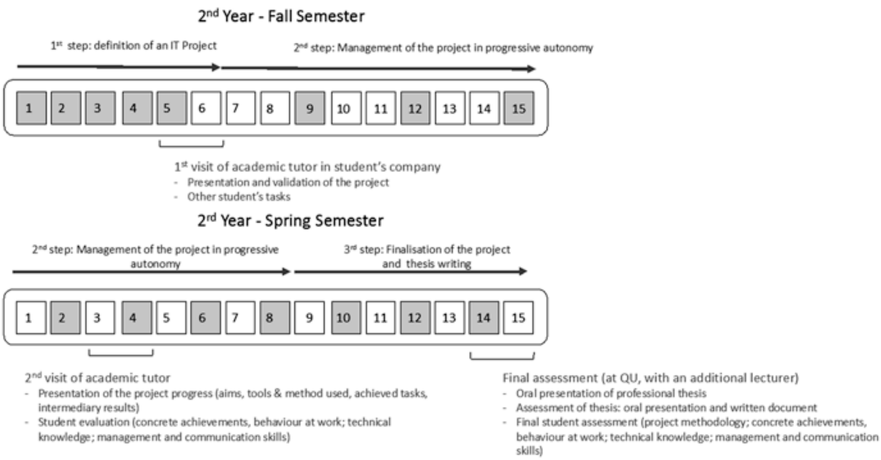
Annex 1: Shorter Version of the Curriculum Proposal (1 Year)



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Chapter 11
Toward a Holistic Approach of Cybersecurity Capacity Building Through an Innovative Transversal Sandwich Training

Jessica El Melhem, Abdelaziz Bouras, and Yacine Ouzrout

Introduction

The contemporary combination of the exponential increase in flows via the Internet and the growing interconnection of players and their data makes cybersecurity a global issue at all scales. In addition, the Millennium Development Goals, through its Agenda for Sustainable Development,[1] make of the technological development

[1] Goal 17: "Strengthen the capacity to implement and revitalize the Global Partnership for Sustainable Development." For technology especially: "17.6 Enhance access to and triangular regional and international cooperation in science, technology and innovation and North-South and South-South cooperation in these areas and improve knowledge-sharing through mutually agreed modalities, including through better coordination of existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism. 17.7 Promote the development, transfer and diffusion of environmentally sound technologies to developing countries on favorable, including concessional and preferential, mutually agreed terms. 17.8 Ensure that the technology bank and the mechanism for strengthening the scientific and technological and innovation capacities of the least developed countries are fully operational by 2017 and strengthen the use of key technologies, in particular information and communications technology."

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and capacity building in this area one of the 17 objectives to be achieved by 2030. From this perspective, cybersecurity and the prevention of cybercrime are major issues in this process, as a means of securing this space for exchange and progress. The estimations show that cyber-attacks cost the world economy around 400 billion euros per year.[2] Also, according to studies conducted by the European Commission, the number of security incidents for all sectors of activity increased by 38% in 2015, in which 80% of European companies were affected by at least one cybersecurity incident in 2015. In addition, 86% of European citizens believe that the risk due to cybercrime is increasing. However, in spite of this growing threat, perceptions and knowledge of cybersecurity issues still remain inadequate: 51% of Europeans feel too little informed about cyber threats, and 69% of companies do not have a basic understanding of their exposure to cyber risks. The ANSSI, the French Network and Information Security Agency (French Network and Information Security Agency 2003), defines cybercrime as the infractions, which violate international treaties or national laws, using information networks or systems as a means of committing or targeting an offense or crime.

Cybersecurity is then based on cyber defense or the set of technical and nontechnical measures enabling a state to defend in cyberspace the information systems deemed essential to set up. Cybersecurity can then be defined as the state sought for an information system that enables it to resist events originating in cyberspace that could compromise the availability, integrity, or confidentiality of the data stored, processed, or transmitted and the related services that these systems offer or make accessible. It uses information systems security techniques and is based on the fight against cybercrime and the establishment of cyber defense (French Network and Information Security Agency 2003).

Cybersecurity, as a condition for technological development and the dynamics of globalization, as well as a tool for sustainable development, concerns each entity (individual, state, organizational, etc.) and thus represents transversal challenges. These challenges go beyond securing information and IT systems alone (management IT, industrial IT, and connected objects, etc.) and now encompass economic, political, and capacity-building strategies (Willemant and Foulgoc 2016).

Also, in the recent years, a topical issue has emerged and became more and more frequent: the theft of data damaging the economy and the reputation for the victim societies. We must therefore address the issue of cybersecurity in a holistic manner to take into account economic, social, educational, legal, technical, diplomatic, military, and other aspects, this showing the growing necessity to integrate transversal skills to the current curriculum.

We will then firstly analyze in our study the different perspectives and approaches and how the various scales deal with cybersecurity.

[2] According to figures from the Council of Europe and the European Union

The International Perspective on Cybersecurity Strategy Enforcement

The Global Cybersecurity Index: A Legitimate Standard Toward a Transversal Assessment of Cybersecurity

In the frame of this international political context, the International Telecommunication Union (ITU), founded in 1865 in Paris on a public-private partnership, organizes its work into three main sectors, through conferences and meetings: the radio communication, telecommunication standardization, and development sectors, including several works on current issues. Today based in Geneva in Switzerland, it is nevertheless widely spread over 12 regional and area offices around the world. ITU members represent a wide range of the global ICT sector, from large global original equipment manufacturer company operators, to small innovative companies using emerging technologies, to large research and development institutes and academic institutions. As other United Nations agencies based on the principle of multilateral cooperation between governments of Member States and the private sector (sector members, associates, academic institutions), ITU is the main global forum in which parties can seek consensus on various issues affecting the future of the ICT sector. Facing the growing necessity for a global and legitimate standard, the ITU has developed a quality standard materialized by the Global Cybersecurity Index (GCI). This index measures the level of development of each country in cybersecurity to raise awareness about this issue (International Telecomunication Union 2015).

The GCI crystallizes an interesting assessment of cybersecurity for three main reasons: its transversality, the measurement of the countries' commitment level to capacity building, and its legal and political legitimacy. Indeed, the GCI aims to "Strengthen ITU's role in building trust and security in the use of information and communication technologies" (International Telecomunication Union 2014). A first iteration of the GCI was carried out in 2013–2014 and improved over the years until the first report was published in April 2015. The GCI combines 25 indicators into a single benchmark measure and assesses and compares the level of commitment of ITU Member States to cybersecurity against the 5 pillars identified above by the high-level group of experts. GCI assesses countries' commitment to cybersecurity following five strategic pillars: legal, technical, organizational, capacity building, and international cooperation. The five pillars of the GCI are briefly explained below:

(a) Legal: measured on the basis of the existence of institutions and legal frameworks dealing with cybersecurity and cybercrime
(b) Technical: measured on the basis of the existence of institutions and technical frameworks dealing with cybersecurity
(c) Organizational: measured on the basis of the existence of cybersecurity policy coordination institutions and development strategies at the national level

(d) Capacity building: measured on the basis of the existence of research and development, education, and training programs; certified professionals and public sector bodies promoting capacity building
(e) Cooperation: evaluation based on the existence of partnerships, cooperation frameworks, and information exchange networks

Thus the main objectives of the GCI are to measure:

(a) The type, level, and evolution over time of cybersecurity engagement within countries and relative to other countries
(b) The progress made by all countries in cybersecurity engagement from a global perspective
(c) The progress in cybersecurity commitment from a regional perspective
(d) The cybersecurity engagement divides, equals to the difference between countries in the degree of their engagement in cybersecurity programs and initiatives

GCI's goal is to help countries identify areas for improvement in cybersecurity, as a tool for motivation, counseling, and following up with the countries so they take action to improve their ranking, thereby contributing to raising the overall level of commitment to cybersecurity worldwide. Through the information collected, the GCI aims to illustrate practices in other countries so that Member States can implement selected aspects adapted to their national environment, with the added benefit of helping to harmonize practices and promote a global culture of cybersecurity. Hence with the creation of this index, an international framework exists, thus paving the way for transversality worldwide in the approach of the cybersecurity. This legitimate and worldwide recognized standard opens up the way for the next step of our study on the understanding of the regional approach of cybersecurity issue, showing the necessity for new pedagogical approaches and inspiring the transversality of our new curriculum's proposal.

Comparative Study at Different Scales: An Insight Toward a Systemic Approach to Cybersecurity

In order to formulate a training responding to the current realities and public policies, it is relevant to learn from the best practices and the degree of compliance of the latter with the five pillars and especially the capacity-building pillar.

In America, the United States before implementing and harmonizing a strategy for cybersecurity would base its regulations on a series of fundamental jurisprudences, among the most fundamental are the 1999 Gramm-Leach-Bliley Act, the 2002 Homeland Security Act, or the Federal Information Security Management Act (FISMA) which were mainly measures arising from the need to protect certain sectors (banking, insurance, etc.).

Secondly, following the 9/11 attacks, the Intelligence Reform and Prevention of Terrorism Act of 2004 (IRTPA) which is a 235-pages Congressional Act was passed and signed by President George W. Bush and renewed the provisions of US federal terrorism laws. Then, the National Intelligence Strategy (NIS) of the United States, a product of the Office of the Director of National Intelligence (DNI), was implemented in 2005 creating a new information sharing system while integrating its existing businesses to achieve its mission and business objectives. The American cybersecurity policy has therefore been at that time, like its modular and jurisprudential legal construction, built on successive layers.

However, starting in 2015 with several Cybersecurity Information Sharing Act (CISA) guidelines, the United States unified its strategy. The December 18, 2015, Act paves the way for the creation of a specific legal framework encouraging the exchange of information between the private sector and the federal government concerning cyber threats and defense mechanisms renewed by the late CISA of December 2017 (House of representative of the U.S. Congress 2017). The United States will also undertake a vast public action campaign in favor of data protection and the strengthening of cybersecurity. The Stop Hacks and Improve Electronic Data Security Act (SHIELD) of November 2, 2017, aims at strengthening cybersecurity in New York State by heightening data security requirements for companies and better protecting New York residents from data breaches of their personal information.

Another example of this vast strategy is the action plan called CNAP for Cybersecurity National Action Plan in early 2016 and funded by 19 billion US dollars in 2017 (The White House and Office of the Press secretary 2016). The priorities are the improvement of:

(a) The protection of the critical infrastructure in the United States and the modernization of government IT.
(b) The identification and the reporting of cyber-attacks to ensure a quick, effective, and coordinate response by increasing the use of multifactor authentication.
(c) The cooperation throughout the development of international partnerships to continue promoting freedom on the Internet and the formation of the Commission on Enhancing National Cybersecurity.
(d) The security of state networks by clearer definitions, measurable objectives, and accountability of federal agencies for achieving these objectives.
(e) The education to shape an informed workforce, aware of cybersecurity issues by expanding its capacity building by establishing a Cyber Corps reserve program, developing a Cybersecurity Core Curriculum, strengthening the National Centers for Academic Excellence in Cybersecurity Program, enhancing student loan forgiveness programs for cybersecurity experts, and encouraging investment in cybersecurity education through the President's Computer Science for All Initiative. The American approach is therefore mirroring the guidelines of the GCI in its transversal structure.

Another example can be taken in Oceania. Australia is the leader and one of the world's leaders in cybersecurity. Like the United States and after several layers of regulations, Australia's Cyber Security Strategy was developed through more than 1.5 years of intensive consultations (Australian Government 2016) with almost 200 organizations of all kinds in Australia and abroad. The national strategy gathers the government and the private sector to establish partnerships and set Australia's strategic agenda as well as jointly design initiatives. This plan sets out five action themes for Australia's cybersecurity by 2020:

(a) A national cyber partnership involving between different structures of different natures including government's department, researchers, and businesses involving regular meetings to strengthen leadership and address emerging issues.
(b) Strengthen cyber defenses to better detect, anticipate, prevent, and respond to risks and threats.
(c) Global responsibility and influence: Cooperate with international partners through their new cyber ambassador to promote a safe, open, and free Internet while strengthening regional cyber capacity to crack down on cybercriminals and close cybercrime refuges.
(d) Growth and innovation: Helping Australian cybersecurity businesses grow and prosper, supporting local expertise to create jobs and growth, and supporting new business models, markets, and investments for all businesses that are made possible by secure products and services.
(e) Reinforcing the capacity-building field by creating a cyber-smart nation based on the training of more Australian cybersecurity professionals through the creation of university centers of excellence in cybersecurity in universities and by developing skills across the education system as well as raising awareness of cybersecurity to enable all Australians to be safe online.

Moreover, Australia continues its efforts to heighten the training of its future generations: The Cyber Security Challenge Australia is an annual cybersecurity competition for Australian postgraduate students organized by an alliance of Australian government, business, academic, and research professionals committed to supporting Australia's next generation of cybersecurity professionals. The contest lasts over 24 hours and tests the technical and communication skills of participants while promoting careers in the field of cybersecurity.

Ranked 6th in the world by the ITU, Mauritius' legal framework makes it one of the continent's and the world's leaders. The authorities implemented four main legislative instruments: an ICT Act in 2001, the Computer Misuse and Cybercrime Act of 2003, the Electronic Transaction Act of 2000, and the Data Protection Act of 2004 that has established the more advanced strategy. It also established the National CERT team under the aegis of the Ministry of ICT and the adoption of the ISO 27001 for the public sector recommended after the official approval of the adoption of the cybersecurity frameworks as part of the National Information and Communications Technology Strategic Plan (NICTSP) (Republic of Mauritius 2014). Within the main policies implemented by Mauritius, the Strategy and Action Plan has been developed to reinforce accountability of governmental structures. The cooperation axe is also a priority: the intrastate, the intra-agency cooperation, the public sector partnership, and the international cooperation following a solid national legislation and reporting mechanisms. Mauritius also created the means for better trainings of future professionals: CERT-MU of the National Computer Board organizes regular trainings to train local ICT professionals on information security and cybersecurity. Certification courses are also organized for both public and private sectors, and postgraduate courses on cybersecurity are offered at tertiary institutions such as the Ministry of Tertiary Education, Science, Research and Technology or the Tertiary Education Commission.

Singapore shows us another successful way. Indeed, in 2016, the National Cybercrime Action Plan (NCAP) in Singapore, the world leader state in cybersecurity, was launched by the Ministry of Internal Affairs (MHA) (Cyber Security Agency of Singapore 2016). The plan sets out the necessary priorities in the action plan to combat cybercrime. These include (a) the need to educate the public about staying safe in cyberspace; (b) the establishment of a cyberspace security information system; (c) the establishment of a cyberspace security information system to combat cybercrime; (d) capacity building in the fight against cybercrime; and (e) development of local laws for international partnerships. Singapore also demonstrates a comprehensive and crosscutting strategy. Also, the National Crime Prevention Council will launch a new app, called the "Cyro" game app, for children later this year, and the Singapore Police Force will go on a mass education campaign in schools to be trained, probably in sandwich trainings based on practical needs matching their daily exercises, which inspires the future curriculum.

Taking now a closer look to the leader countries in the Arab world, Qatar is one of the leaders in cybersecurity. During the last decade, Qatar started an industry diversification strategy based on a knowledge-based economy for the next years. Qatar's ambition is to become a global "hub" in some key fields such as new technologies, finance, culture, and sporting events, thus hosting worldwide cup of 2022 and developing infrastructures and cybersecurity. In this context, Qatar faces several types of threats, among them are hacktivists, advanced persistent threats (APT), cybercrime syndicates, and malicious insiders. In 2013, Qatar established the National Cybersecurity Committee (Committee) to provide a governing structure to address the issue of cybersecurity in a collaborative and high-level manner. The Committee developed the Qatar National Cyber Security Strategy (NCSS), which represents a model for moving forward and improving Qatar's cybersecurity.

Qatar's vision on cybersecurity is: "To create and maintain a secure cyberspace to safeguard national interests and preserve the fundamental rights and values of Qatari society" (Minister of Information and Communications Technology 2014). This plan combines good governance with a set of cybersecurity initiatives, measures, and awareness programs that will develop an effective long-term protection strategy. The NCSS is based on the deep understanding of the threats, risks, and challenges facing Qatar. The chapters describe the challenges, capabilities, and steps toward an efficient cybersecurity. More especially, Chap. 3 describes Qatar's strategic approach to national cybersecurity. Qatar's vision is to find a compromise by establishing and maintaining a secure cyberspace to safeguard national interests as well as preserving the fundamental rights and values of Qatari society. This vision is illustrated by five steps aiming at its implementation:

(a) Safeguard the national critical information infrastructure.
(b) Respond and resolve cyber incidents and attacks in a timely and effective manner through information sharing, collaboration, and action.
(c) Establish a legal and regulatory framework to enable a secure and dynamic cyber environment by increasing their capacity to fight cybercrime and develop, monitor, and enforce regulations on cybersecurity and compliance to standards.
(d) Foster a culture of cybersecurity that promotes the safe and appropriate use of information and communication technologies.
(e) Develop and develop national cybersecurity capacities.

Qatar is also very involved in the fight against cybercrime, as at the 5th INTERPOL Global Conference on Trafficking in Human Beings and Smuggling of Migrants, held in Doha on December 6 and 7, 2017, and the 1st Major Event Safety and Security Conference, held in Doha on November 7 and 8, 2017. Launched by INTERPOL in 2012 and funded by Qatar, this 10-year project aims to create a Centre of Excellence to help INTERPOL's 192 member countries undertake police and security preparations for major sporting events. It will help support capacity-building activities and police operations at major events by providing host countries with unique knowledge and facilitating the secure exchange of real-time information on incidents and emerging emergencies. The knowledge management system consolidates the learning accumulated since Project Stadia's inception in 2012 through expert meetings on legislation, physical security, and cybersecurity, as well as training courses with partners including NCS4 (National Center for Spectator Sports Safety and Security at the University of Southern Mississippi). In terms of capacity building, several proposals of curricula are currently under review at the University of Qatar in order to provide new sandwich trainings in cybersecurity involving a partnership between the academic and the industrial sector and thus promoting also a new educational culture.[3]

The Newborn European Protective Framework

The European Legal and Policy Layout

In the framework of the European Union, the "Internet of Things" is already widespread, to the point where the EU is predicted to have tens of billions of connected digital devices by 2020. Therefore, a draft directive (European Parliament; Council of the European Union 2013) of the European Parliament and Council is currently being implemented: It concerns measures to ensure a common high level of network and information security in the Union which would impose a minimum level of security for digital technologies, networks, and services in all Member States. The

[3] Framework of Experiential Learning to Enhance Student Skill Collaborative Learning

text also proposes obligations and reporting mechanisms for companies and organizations. The EU Cyber Security Strategy sets out the EU's approach to prevent and respond better to cyber disruptions and attacks. It reviews a series of actions to increase cyber resilience of computer systems, reduce cybercrime, and strengthen the EU's international cybersecurity and cyber defense policy to protect cyberspace, in both civil and military areas.

On July 6, 2016, after 3 years of negotiations, the European Parliament and the Council of the European Union adopted the directive on the security of networks and information systems under the name "Network and Information Security (NIS) Directive" (European Parliament and Council of the European Union 2016). The NIS Directive is the security counterpart of the European Digital Single Market Strategy, launched in 2015, which aims to make digital an engine of growth: Business and consumer confidence is essential for this project, because without confidence, there can be no growth. This directive provides for the strengthening of national cybersecurity capacities: In particular, Member States will need to establish national cybersecurity authorities, national computer incident response teams (CSIRTs), and national cybersecurity strategies. In its September 2017 reform package, the European Commission proposed the introduction of EU-wide cybersecurity certification schemes for ICT products, services, and processes. This initiative aims to foster the growth of the European cybersecurity market. The International Cybersecurity Forum is part of a process of reflection and exchanges aimed at promoting a European vision of cybersecurity and strengthening the fight against cybercrime, a priority of the European Union as set out in the 2010–2015 Stockholm European Program. The European Cybersecurity Organization (ECSO) was established in June 2016 with the objective of assisting projects that would develop, promote, or encourage cybersecurity initiatives in Europe. May 9, 2018, was the deadline for the transposition of the NIS Directive into national law. The European Union Agency for Network and Information Security (ENISA), with which ANSSI works closely, will be responsible for assisting Member States in the proper implementation of the Directive. A Cooperation Group, composed of national representatives as well as the ENISA and the European Commission, will provide strategic orientations, and a network of CSIRTs will also be organized and will be able to ensure communication and exchange of good practices, as well as support Member States on matters related to the Directive.

The French Management of Cybersecurity: A Budding Transversal Attempt

Jean-Marc Ayrault, Prime Minister in 2014, declared on February 21, 2014, that "Cybersecurity is a matter of major interest and national interest that concerns all citizens, all French people, and that is why it is important that the government is fully committed." And Ms. Axelle Lemaire, Secretary of State for Digital Affairs, said on July 6, 2015: "The Government will present a comprehensive national strategy on cybersecurity as of the start of the next school year." On October 16, 2015, Prime Minister Manuel Valls submitted the National Digital Security Strategy which must be based on training and international cooperation (proposal to draw up a roadmap for Europe's digital strategic autonomy; increased participation by France in multilateral negotiations on cybersecurity within the UN and the OSCE). This strategy, drawn up with all the ministries, sets the objectives to be achieved and guidelines to strengthen the security and defense of our critical infrastructures and to accompany the digital transition by defining the human, technical, and operational levers necessary for innovation, economic development, and the confidence of the French people in digital technology. In the Framework of the implementation in France of the European Strategy, the National Information Systems Security Agency (ANSSI), the CERT-FR, and the national strategy for digital security aim at creating:

(a) The establishment of a framework for voluntary cooperation between states including the creation of a cooperation group of Member States on the political aspects of cybersecurity and a European CSIRT network of Member States. The latter will aim in particular at facilitating the sharing of technical information on risks and vulnerabilities.
(b) The reinforcement by each state of cybersecurity of "operators of essential services"[4] (OVI) to the functioning of the economy and society by extending the notion of operator of vital importance (OVI), by unifying at the national level the cybersecurity rules with which they will have to comply and the obligation for operators to notify incidents having an impact on the continuity of their essential services.
(c) The establishment of common European rules on cybersecurity for digital service providers in the areas of cloud computing, search engines, and online marketplaces.

France is now working on the transposition of the NIS Directive (Journal Official 2018). The Military Programming Law (or MPL) was created in 2013 under the government of Jean-Yves Le Drian to tackle the issue of cybersecurity in a comprehensive and coherent manner. Its objective is to require certain economic or public operators to secure their so-called "vital" information systems. Also, Article 15 of the Military Planning Law for 2014–2019 (voted in December 2013) (Institut des Hautes Etudes de la Securité et de la Justice 2015) details the obligations that the Prime Minister imposes on OVI in terms of security including setting up a computer attack detection equipment or provides criminal sanctions in the event of noncompliance (approximately 200 IVOs, 120 in the private sector and 80 in the public

[4] Defined by Article R1332–1 of the Defense Code. In France, an operator of vital importance (OVI) is an organization identified by the state as having essential or dangerous activities for the population.

sector). The federations of the electrical, electronic, and communication industries also ensure the liaison of their respective works.

The Military Programming Law (MPL) will structurally modify the various organizations of the company by its implementation and by the various impacts in its operation, in particular by the rules related to the security of information systems (Institut des Hautes Etudes de la Securité et de la Justice 2015). However, if safety is to be efficient, it must not only be seen as a technical problem. It is above all a management and governance problem, which is crucial to realize to propose the next generation of curriculum accordingly. The Military Programming Law will have impacts on the:

(a) Legal frame: with the question on how to apply the various legal provisions without being outlawed, including the study of the compliance between the limits set by the MPL and the patents, for example.
(b) Organizational frame: the internal organization of the OVIs must be modified and adapted to meet the various constraints of the MPL.
(c) Technological frame: according to the directives of the MPL, a diversity of technologies will be deployed to meet the various prescriptions and change management at the technical level.
(d) Financial frame: implementation has a cost associated with organizational changes, the implementation of new technical devices, their operation, and their control.

Following these international practices, standards, and recommendations, France aligned creating a “France Cybersecurity” label to raise user awareness, attest to the quality and functionalities of labeled products and services, promote French cybersecurity solutions in France and internationally, and increase their visibility and use to raise the level of user protection. Also, we observe, especially for companies, that at the national level, the directive requires in particular the establishment of a cybersecurity strategy, the establishment of a CSIRT, and an authority in charge of these topics. For companies, it introduces two types of obligation depending on the type of actors: The essential services operators must implement technical and organizational measures to prevent the risks threatening the security of networks and information systems, and the digital service providers must report these security incidents to the competent authority following the good practices in many leader countries in cybersecurity.

We observed that the global trend is now to integrate at all levels the pillars recommended by the GCI. Whether in terms of regulations, governance, public policies, or action plans, the cybersecurity is now an issue that needs to be approached in a systemic way. The capacity-building field followed the same evolution through times, becoming more holistic, diverse, and multifaceted thus mirroring the global governance and needs. However, in the continuity of this trend, there is an urge to deepen this transversality in the current trainings.

The Lack of a Comprehensive Approach in the Existing French Trainings

The Emerging Drive for Crosscutting Trainings Meeting Cybersecurity Management Needs

Cybersecurity is an ever-changing system that does not define itself anymore as the management of the technical area. Following the international best practices and in order to prevent effectively threats, a holistic approach encompassing not only technical skills but soft skills is crucial (Ali et al. 2015). Peter Fisher, fellow chair of the the Institute of Information Security Professionals (IISP) and the Training Accreditation Committee, points out the fact that the demand for cybersecurity is exponential and can no longer be met by practitioners coming from other fields, but rather practictionners who should be trained on the various aspects of cybersecurity.

A study carried out by EY firm on behalf of OPIIEC shows that most of the professions in the cybersecurity sector in France are structured around five large family blocks (Cabinet 2017). These business families are the current trends to respond to answer needs:

1. The first business family concerns “Safety Management, Organization and Risk Management” which aims to bring together all the businesses with strong responsibilities in terms of safety management of the company’s information system and the management of the risk. These professions play a direct role in the definition of the company’s security strategy and are responsible for the development of the security corpus of documents and the crosscutting analysis of threat, risks, and responses.
2. The second business family is about “Security Project Management and Security Life Cycle” family, which brings together all the businesses that play an important role in all information system security development projects including the supervision.
3. The third business family, called “Maintenance in Operational Security Condition,” covers all operational businesses in charge of configuring, deploying, and applying security measures to the company’s technical infrastructure (network, system, and security).
4. The fourth business family encompasses the “Security Incident Support and Management” related businesses that are directly involved in cybersecurity incidents (viral infection, ransomware or ransom software, information leaks, etc.). They participate in the continuous improvement of detection and prevention methods (security monitoring, security controls, etc.) of security incidents, which they also handle.

5. Finally, the fifth family includes the "Security Consulting, Audit, and Expertise" family which brings together cybersecurity professions carrying out expertise missions in cybersecurity. These experts are generally directly employed by companies to meet a specific need or to provide an external guidance.

In addition, the IISP has launched a new version of its Skills Framework, widely accepted as the de facto standard for measuring the knowledge, experience, and competency of information security and assurance professionals. The IISP aims at providing better training courses adapted to the emerging transversality required in cybersecurity management. Indeed, the new framework includes new skills groups for threat intelligence and assessment, threat modelling, cyber resilience, penetration testing, and intrusion detection and analysis as well as incident management, investigation, and response while also expanding the roles of enterprise and technical security architecture and redefining the skills profile for audit, compliance, and testing. The IISP also highlights the needs on management, leadership and influence, business skills and communication, and knowledge sharing.

The Preponderance of Technical Skills in the Existing Labeled Trainings in France

In France, there are nearly 150 long training courses provided by higher education institutions including more than 400 short training modules provided by continuing education bodies. However, in 2016, the ANSSI wanted to improve the referencing of digital security training by setting up a labeling process that tests and guarantees the relevance of the training with its goals. A training labeling program called "SecNumEdu" was launched, unveiling 26 SecNumEdu-labeled training courses. They include seven masters, five specialized masters, eight professional licenses, and six engineering courses. This labeling program presents several goals.

The first one is to provide a quality standard to potential students and employers. The SecNumEdu label also tends to participate in the strengthening and development of digital security education. Indeed, this label is based on a labeling reference framework, the development of which was piloted by ANSSI with the contribution of industrialists, schools, the Pôle Excellence Cyber (PEC), and the Ministry of National Education, Higher Education Institutions and Research. It is awarded for a renewable period of 3 years and allows the training that benefits from it to appear in the ANSSI's SecNumEdu catalogue. In the current labeled trainings, the main expected technical skills are application security, access and identity management, and security audit. In addition we observe that the main expected functional skills are protection of information, business continuity management, and cybersecurity monitoring. Finally, the three major desired transversal capacities are adaptability and flexibility, respect of confidentiality rules, and intellectual curiosity.

Other trainings as well as additional labels may be examined. Indeed, this training labeling program is opened to any higher education institution meeting one of the following criteria: university courses delivering a bachelor or master degree, engineering courses whose diploma is recognized by the Engineering Titles Commission (or Commission des Titres d'Ingénieurs (CTI)), specialized masters recognized by the Conference of Grandes Écoles (CGE), and Level I and II certifications listed in the National Occupational Certification Directory (or Répertoire national des certifications professionnelles (RNCP)). The ANSSI is in charge of the certification process and maintains an updated database of the training courses.

These trainings all incorporate the same structure integrating 6 to 54 students each year: face-to-face courses, distance learning courses, massive open online course (MOOC), practical work in class, remote practical work, projects, exchange semester abroad, sandwich course, and internships. For the vast majority, they integrate the following soft skills: law and regulation, social and societal aspects, postmortem analysis (forensic), cybersecurity policy, and economic aspect of security.

Although demonstrating transversality in the approach of the cybersecurity capacity building, those trainings leave a room for improvement, especially as they do not reflect the variety and the complexity of the business families and needs described above.

Proposal of an Innovative Soft Skills Sandwich-Based Curriculum

The Sandwich Training: An Efficient Customized Training Form Responding to Cybersecurity Challenges and Individual Needs

The complexity and the multi-sidedness essence of the cybersecurity phenomenon involved very quickly the necessity for a holistic form of training.

Indeed every aspect of the cybersecurity requires a unique approach. This way, this new curriculum presents, for each new course, the diverse pedagogical methods including face-to-face courses, distance learning courses, practical work in class, remote practical work, projects, internships, and, most of the time, vocation learning in the workplace (see Table 11.1). We know that both training and education are crucial in developing and ensuring the necessary cybersecurity know-how.

Therefore, the new curriculum model aims at combining distinct specific and practical skills necessary (see Fig. 11.1) for an efficient training (Ali et al. 2015) designed to create a synergy between two types of public:

- Employees from companies willing to improve their skills or acquire new knowledge through continuing education
- Students following the initial training searching for a practical skills

Table 11.1 Comparative table on the national strategical frameworks for cybersecurity prevention per country

National strategical frameworks for cybersecurity prevention per country	Date	Legal framework	Technical framework	Organizational framework	Capacity building	Cooperation
United States: GCI, 0,919; global rank, 2nd						
Cybersecurity Information Sharing Acts (CISA)	December 2015	Exchange of information between the private sector and the federal government concerning cyber threats and defense mechanisms				
Cybersecurity National Action Plan (CNAP)	February 2016	Ensuring the security of state networks by clearer definitions, measurable objectives, and accountability of federal agencies for achieving these objectives	Modernization of Government IT	Identification and reporting of cyber-attacks	Establishing a Cyber Corps reserve program, developing a Cybersecurity Core Curriculum, strengthening the National centers for Academic Excellence in Cybersecurity program, enhancing student loan forgiveness programs for cybersecurity experts, encouraging investment in cybersecurity education through the President's Computer Science for All Initiative	Coordinate response by increasing the use of multifactor authentication and development international partnerships to continue promoting freedom on the Internet and the formation of the Commission on Enhancing National Cybersecurity

(continued)

Table 11.1 (continued)

National strategical frameworks for cybersecurity prevention per country	Date	Legal framework	Technical framework	Organizational framework	Capacity building	Cooperation
Stop Hacks and Improve Electronic Data Security Act (SHIELD)	November 2017		Heightening data security requirements for companies and better protect New York residents from data breaches of their personal information			
Australia: GCI, 0,824; global rank, 7th						
National Strategy	2020		Strengthening cyber defenses to better detect, anticipate, prevent, and respond to risks and threats	Helping Australian cybersecurity businesses grow and prosper, supporting local expertise to create jobs and growth, and supporting new business models, markets, and investments for all businesses that are made possible by secure products and services	Reinforcing the capacity-building field by creating a cyber smart nation based on the training of more Australian cybersecurity professionals through the creation of university centers of excellence in cybersecurity in universities and by developing skills across the education system as well as raising awareness of cybersecurity to enable all Australians to be safe online and the creation of the Australian Cyber Security Challenge	Global responsibility and influence: cooperate with international partners through their new cyber ambassador to promote a safe, open, and free Internet while strengthening regional cyber capacity to crack down on cybercriminals and close cybercrime refuges

Mauritius: GCI, 0,830; global rank, 6th						
Data Protection Act	June 2004			Reinforce accountability of governmental structures	Strengthening the CERT-MU of the National Computer Board to organize regular trainings and local ICT professionals on information security and cybersecurity. Certification courses are also organized for both public and private sectors, and postgraduate courses on cybersecurity are offered at tertiary institutions such as the Ministry of Tertiary Education, Science, Research and Technology or the Tertiary Education Commission	Strengthening the intrastate, the intra-agency cooperation, the public sector partnership, and the international cooperation following a solid national legislation and reporting mechanisms
Singapore: GCI, 0,925; global rank, 1st						
National Cybercrime Action Plan (NCAP)	July 2016	Development of local laws for international partnerships	The establishment of a cyberspace security information system to combat cybercrime and launching of a new application		The need to educate the public about staying safe in cyberspace and capacity building in the fight against cybercrime, the Singapore Police Force will go on mass education campaign in schools, probably using sandwich trainings based on practical needs matching their daily exercises	Development of local laws for international partnerships

(continued)

Table 11.1 (continued)

National strategical frameworks for cybersecurity prevention per country	Date	Legal framework	Technical framework	Organizational framework	Capacity building	Cooperation
Qatar: GCI, 0,676; global rank, 25th						
Qatar National Cyber Security Strategy (NCSS)	May 2014	Establish a legal and regulatory framework to enable a secure and dynamic cyber environment by increasing their capacity to fight cybercrime and develop, monitor, and enforce regulations on cybersecurity and compliance to standards	Safeguard the national critical information infrastructure	Respond and resolve cyber incidents and attacks in a timely and effective manner through information sharing, collaboration, and action	Develop a national cybersecurity capacities	Foster a culture of cybersecurity that promotes the safe and appropriate use of information and communication technologies
European Union						
The European Cybersecurity Organization (ECSO)	June 2016			Assisting projects that would develop, promote, or encourage cybersecurity initiatives in Europe		
Network and Information Security (NIS) Directive	June 2017	The establishment of common European rules on cybersecurity for digital service providers in the areas of cloud computing, search engines, and online marketplaces		Member States will need to establish national cybersecurity authorities, national computer incident response team, and national cybersecurity strategies		Establishment of a framework for voluntary cooperation between states: creation of a cooperation group of Member States on the political aspects of cybersecurity and a European CSIRT network

EU-wide cybersecurity certification schemes	September 2017		Strengthening ICT products, services, and processes			
France: GCI, 0,819; global rank, 8th						
National Digital Security Strategy	October 2015			Extending the reinforcement of the "operators of essential services" (OVI) to the functioning of the economy and society by extending the notion of operator of vital importance (OVI) and unifying at the national level the cybersecurity rules with which they will have to comply and the obligation for operators to notify incidents having an impact on the continuity of their essential services		Proposal to draw up a roadmap for Europe's digital strategic autonomy; increased participation by France in multilateral negotiations on cybersecurity within the UN and the OSCE
Military Programming Law (MPL)	December 2013	Applying the various legal provisions without being outlawed, including the study of the compliance between the limits set by the MPL and the patents, for example	Setting up a computer attack detection equipment or provides criminal sanctions in the event of noncompliance, and a diversity of technologies will be deployed to meet the various prescriptions and change management at the technical level	The internal organization of the OVIs must be modified and adapted to meet the various constraints of the MPL, and implementation has a cost associated with organizational changes, the implementation of new technical devices, their operation, and their control	Creation of a "France Cybersecurity" label to raise user awareness	

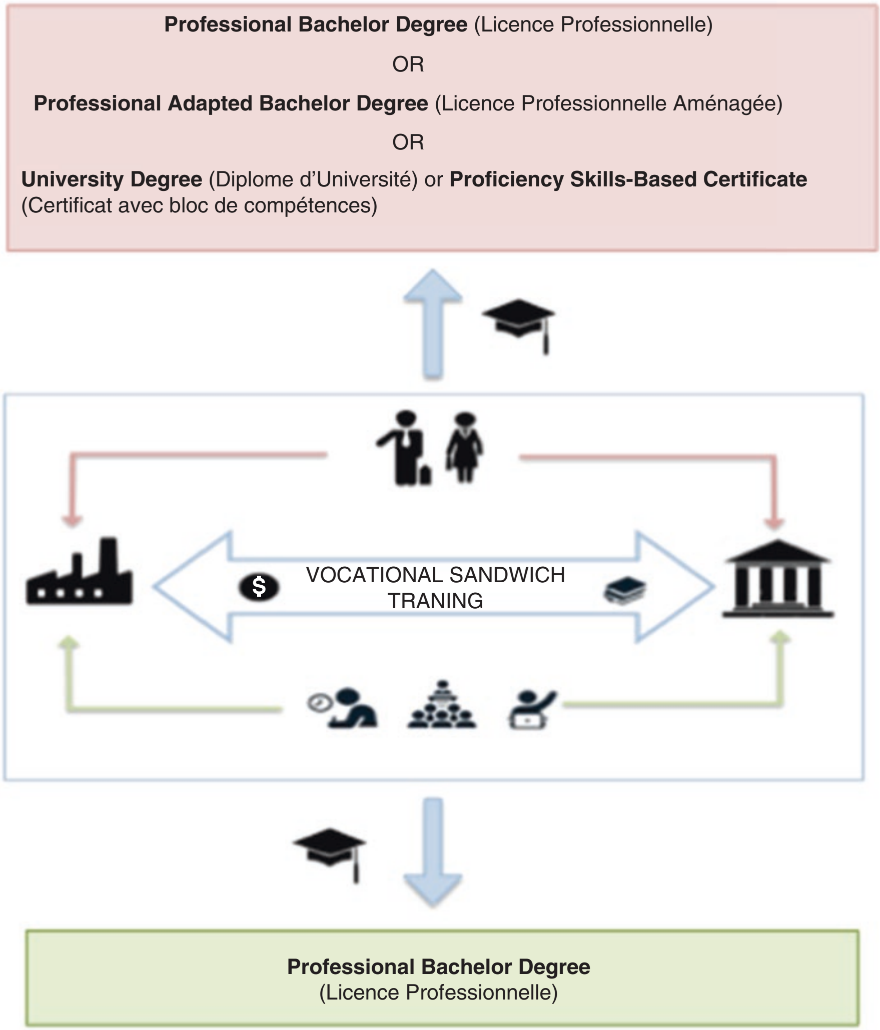

Fig. 11.1 The vocational sandwich training model and the various options of graduation for students and employees

This alternation training mode presents two main advantages.

The first one concerns the training of employees aiming at responding to their growing need to either gain firsthand knowledge after a vocational retraining or develop additional skills and complementary expertise to their day-to-day know-how.

This training aims at answering the expanding demand in terms of customized program corresponding to each profile.

The second advantage of such a sandwich training concerns the students, permitting them to acquire a firsthand and practical knowledge of the cybersecurity challenges. Indeed the alternation of the training period formation at the university and on the workplace allows them to get familiar with the threats, the risk prevention, and how the battle for cybersecurity is managed through a holistic approach to assessment, governance, risk measurement, and coordinated answer.

This alternation process is also crucial for the reflexivity it offers between the theoretical knowledge and the workplace needs. Indeed this practical environment would allow the students to link their puzzled skills and thus achieve a wider and deeper understanding and practice of the cybersecurity challenges.

Consequently, students could get a professional bachelor degree, while the employees could get, depending on the courses attended and the skills acquired as well as the assessment method, a professional bachelor degree, a professional adapted bachelor degree, or a skills-based certificate (Fig. 11.1).

A Holistic Skills-Based Training

As proposed by the ITU and the several governance strategies worldwide, as well as the different business families, cybersecurity issue is not anymore an isolated field but linked to other social and political issues, which needs to be addressed by a systemic manner in order to mirror this transversality promoted and ranked by the GCI. In the labeled problem today in France, there is no such training reflecting those needs and encompassing the whole facets of cybersecurity. Thus, there is an emergency to rethink the current trainings and to integrate to it new soft skills and creativity (Patrick and Fields 2017) never experimented before such as the organizational and cooperation skills including the understanding of the strategy and governance involved in the cybersecurity process as well as the risk management. Also, as cybersecurity implicates in its core the management of threats in the cyberspace, an innovative approach encompassing the study of several branches of Psychology (such as Forensics, Social, Cognitive, Behavioral, and Organizational Psychology) to grasp the mental processes of the offenders as well as the human-computer interaction (Brave and Nass 2002) seems henceforth necessary to better apprehend the threat, prevent it, or, where relevant, respond to it more efficiently. In the same way Human Resources Management as well as social and economic aspects are relevant to organize the implementation of cybersecurity at the micro and the macro level.

One year of study through the existing LMD system includes 60 credits. As a consequence, 30 credits should be given to technical know-how, while 30 credits should be allocated to soft skills as presented hereafter (Table 11.2):

Table 11.2 Proposal of a new curriculum content

Course	Content	Training approach	Credits
Law and Regulations	1. *Doctrine* Introduction to international law and cybercriminality Comparative study on different regions: local and cultural approach to cybersecurity 2. *Litigation* Regulations in Europe and France Jurisprudence and introduction to litigation methods	Face-to-face courses Distance learning courses Practical work in class	5
Social and economic aspects	1. *Microeconomics:* the challenges at the company's scales 2. *Macroeconomics:* the challenges at the state's scales 3. *Sociology*: cyber threats, economical and sociological motivation and impacts	Face-to-face courses Distance learning courses Practical work in class	5
Risk management	1. *Study of the whole chain* from mitigation of risks to business continuity plan and gambling 2. *IRM method:* frame that integrates risks together and systemic analysis 3. *Postmortem analysis* (forensic)	Face-to-face courses Distance learning courses Practical work in class Sandwich course Internships Serious games	5
Introduction to Psychology	1. *Introduction to several branches of Psychology relevant for cybersecurity:* Forensic Psychology and Criminology, Social Psychology, Cognitive Psychology, Behavioral Psychology, and Industrial-Organizational Psychology (especially the human-computer interaction, the study of organizational processes, leadership) 2. *Case studies and simulations*	Face-to-face courses Practical work in class Remote practical work Projects Sandwich course Internships Serious games	5

Strategy and governance	1. *International standards* organizations and standards 2. *Organizational skills and understanding*: top-down practices and public policies 3. *Resilience management and strategy*	Face-to-face courses Distance learning courses Practical work Remote practical work Projects Sandwich course Internships	5
Human Resources	1. *Basics* of Human Resources 2. *Crosscutting risks and Human Resources* applied to the human risk management, communication, etc. 3. *Business continuity management*	Face-to-face courses Distance learning courses Practical work in class Remote practical work Projects Sandwich course Internships	5

Conclusion

Our comparative study revealed that cybersecurity still suffers from each region's cultural particularism, showing room left for universality, harmonization, and the sharing of information and good practices. Nevertheless, the clear balance sheet reveals the global consciousness and the emergency for a holistic and creative approach, especially that of cybersecurity capacity building (Patrick and Fields 2017). Indeed, in the frame of the awareness rising about cybersecurity, many organisms and standards arose to define and measure this phenomenon. The Global Cybersecurity Index (International Telecomunication Union 2015) created by the International Telecommunication Union of the United Nations is one of them. Hence, it enjoys a great degree of legitimacy and paves the way of global and transversal standards in cybersecurity based on the existence of five pillars: the legal framework, the technical know-how, the organizational structures, the cooperation processes, and the capacity-building strategy. These pillars are thus great tools and guidelines for assessing the existing trainings in cybersecurity on one hand and implementing a new curriculum based on transversal skills on another hand.

Also, the various public policies are not anymore involving only technical know-how (Ali et al. 2015) but are rather a reflection of a top-down governance comprising many societal layers as well as the consideration of the new emotions' management related to the cyberspace (Brave and Nass 2002). Nevertheless, after examining the content of the existing trainings in cybersecurity in France (National Information Systems Security Agency of the Secretary General for Defence and National Security 2018), we observed that most of them are still following the classical scheme of duality between technical skills and legal/economical skills thus showing up at least two needs: the need for a larger typology of skills involved on one hand and the need for a more practical attempt to grasp the complex reality of cybersecurity through sandwich trainings on the other hand.

Therefore, the new curriculum model would aim at combining distinct skills such as the organizational and cooperation skills including the understanding of the strategy and governance involved in the cybersecurity process as well as the risk management. Also, as cybersecurity implicates in its core the management of threats in the cyberspace, an innovative approach encompassing the study of several branches of Psychology (such as Forensics, Social, Cognitive, Behavioral, and Organizational Psychology) as well as Human Resources to grasp the mental processes of the offenders as well as the human-computer interaction (Brave and Nass 2002) seems henceforth necessary to better apprehend the threat, prevent it, or, where relevant, respond to it more efficiently at the micro and the macro level.

By its sandwich form – closer to the workplace realities – and its holistic content encompassing better the complex challenges, the newborn sandwich training we propose is designed to answer to a large public demand and a wider approach, thus building the effective skills for the future generation to manage cybersecurity.

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Chapter 12
The Toolkit: Pedagogies, Curricular Models, and Cases for Engineering Academics and Schools Implementing Industry-Integrated Engineering Education

Mahmoud Abdulwahed

Introduction

In this chapter, we highlight a number of pedagogies and curricular frameworks and models as toolkit for engineering education academics and schools for facilitation of the implementation of industry-integrated engineering education. In particular, we provide further details on competency-based education (Frank et al. 2010; Kenkel and Peterson 2010; Morcke et al. 2013; Johnstone and Soares 2014) and a number of learner-centric, constructivist, and experiential pedagogies (Abdulwahed et al. 2008) such as service-based learning (Bringle and Hatcher 1996; Waterman 2014), high-impact practices (Brownell and Swaner 2009; Kuh 2008), problem-/project-based learning (Mills and Treagust 2003; Abdulwahed et al. 2009), engineering design (Dym et al. 2005; Abdulwahed and Hasna 2017), etc. The learner-centric approaches are in particular useful for executing on competency-based education models in practice in the classroom and curricular delivery. Competency-based education is in particular a suitable framework for implementing industry-integrated engineering education because CBE emphasizes the combination of the following triangulation in situation, context, or professional activity:

1. Knowledge
2. Attitude or value
3. Skill or ability

These three components can be an optimal setup to systematically design an effective industry-integrated engineering education for the following rationales:

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- The context to be chosen will be a professional industry context in which the competency in the engineering education is designed around.
- Knowledge of theory and information of this context need to be taught in engineering education (e.g., engineering theory and content knowledge for industrial context).
- The proper professional attitude and value for this professional context need to highlighted and potentially practiced (e.g., professional ethics, professional behaviors, etc.).
- The skill or ability to perform and execute on the professional context needs to be trained in engineering education (e.g., lab, practicum, internships, etc.).

In the next section, further details on competency-based education are provided.

Competency-Based Education: A Holistic Framework for Implementing Workplace Competencies in Engineering Education

Competency (Mastery)-Based Education

Competency-based education (CBE) ensures graduates are produced with necessary levels of mastery for their next station (career or further studies), they are flexible systems that admit learners with demonstrated competency at the proper level and allows time variants for mastery attainments.

Competency-based education (CBE) is a paradigm shift in which it distinguishes itself from traditional education models with the following:

1. The central focus of the education system is on students' competency development and mastery.
2. These competencies are defined in close alignment with workplace and contextual needs.
3. Learning outcomes (outcome-based education (OBE)) is central, and the time for achieving it is variant (not fixed by completion of a number of credit hours).
4. Provides flexibility in the way that credit can be earned or awarded and offers students personalized learning opportunities.
5. Ensure that more students who succeed in academia build career readiness.
6. CBE is highly learner-centric and experiential based.

Transformation from traditional into competency-based education has implications on the following:

1. *Delivery*: mainly using learner-centric and experiential approach, as well as digital-based learning

2. *Curriculum design*: mainly comprehensive integration of competencies of workplace and context in curriculum
3. *Competency framework, learning outcomes, and competency assessment*: a need to develop a systematic competency framework and moving from traditional exam-based assessment toward competency-based assessment that focuses more on mastery and process development

Definition of a Competency There are several definitions of competency, and in many times, the term competency is interchangeably utilized by other terms. In this chapter, we are utilizing the following definition of competences: "A competence is the **INTEGRATION** of **KNOWLEDGE**, **SKILLS/ABILITIES**, and **ATTITUDES** (or values) which **SITUATIONALLY** allow a person to **DEVELOP** effectively in different contexts and **PERFORM** a **FUNCTION**, **ACTIVITY** or **TASK** in proper way." The model we are adopting for competency definition is represented in Fig. 12.1.

Approaches to Develop Competency (Mastery)-Based Education

Competency-based education is rather a generic framework that several approaches can be considered under its umbrella. We highlight below some of these approaches:

Workplace Competency Development in the Curriculum: This should come as the first stage of transformation of engineering school curricula into CBE. The main aim of this phase is to develop comprehensive set of competencies and curricular programs based on workplace and contextual needs that Qatar University aims to serve. There are several models and frameworks for this, and one of the widely utilized methods is called DACUM (Developing A CurriculUM).

Fig. 12.1 Conceptual model of a competency which is represented by the integration of knowledge, skills/abilities, and attitude/value to handle a situation, context, or professional activity

Formal Credentials for Attained Competencies (Formal or Informal): This is one of the characterizing foundations of CBE systems, which normally allows acknowledgment of developed competencies in terms of previous experience, informal learning, or training by provisioning formal credentials upon demonstrating satisfactory mastery level via CBE assessments.

Variation of Time to Degree Completion: This is another foundational principle of CBE systems; the main target is demonstration of mastery of certain set of competencies to attain a degree. The time to complete a degree would depend on the learners' ability to reach a certain mastery level.

Engineering Graduate Attributes Framework

Engineering graduate attributes define a selected set of attributes that students of an engineering school should develop during their time in college. Engineering graduate attributes should be strongly aligned with national attributes and competency needs (e.g., attributes identified by the Ministry of Education on K–12 level, digital literacy, national visions, etc.), as well as the employer needs (e.g., technical competency, leadership, etc.). The engineering attributes are qualities that prepare graduates to succeed in their personal and professional lives. Each attribute is composed of a set of competencies; the latter are by-product of program learning outcomes. The engineering graduate attributes model defines the key competencies to be acquired by all students that will enable the development of the desired graduate attributes. These competencies represent the desired knowledge, skills/abilities, and attitudes/values (KSA) to be acquired by the engineering students during their time at the engineering school. On a high-level sketch of Engineering Competency Framework, the following dimensions should be identified:

- Contextual and National Competencies: e.g., K–12 comp., government and employer competencies, etc.
- Universal Competencies (for all): e.g., twenty-first-century, employability, KBE citizens, national, and other competencies
- Profession Specific (for professional domain-specific personnel): e.g., engineering profession
- Discipline Specific: e.g., civil engineering, mechanical engineering, etc.
- Vertical Specialization and Mastery: e.g., those careers on advanced R&D or high specializations (normally not at UG level)
- Functional, Situational, and/or Workplace Performance Competencies: e.g., welding, coding, calling, curating, etc.

Universal competencies can be classified into three dimensions:

- Cognition, thinking, and mental
- Interpersonal and professional
- Business and management

For profession, discipline, or vertical competencies, the KSA classification (described earlier and shown in Fig. 12.1) can be utilized:

- Core knowledge
- Core skill/ability/practice
- Core attitudes/traits

Pedagogical and Curricular Models for Facilitation of CBE Implementation

Constructivist Learning

Constructive learning (students construct knowledge and experience by their own) is a framework umbrella for several learner-centric and experiential approaches such as (Richardson 2003) (1) active learning, (2) flipped classroom, (3) experiential learning cycle and styles, (4) project-/problem-based learning, (5) research-based learning, (6) community- and service-based learning, (7) collaborative learning, (8) entrepreneurial learning, (9) design-based learning, (10) competency-based learning, (11) inquiry-based learning, (12) seminar-based learning, (13) internships, (14) field visits, etc. With the advancement of ICT, digital tools and learning technologies have become significant enabler of implementations of constructivist learner-centric and experiential pedagogy approaches.

High-Impact Practices (HIPs) in Undergraduate Education

This is a new trend gaining momentum in the USA. HIPs are practical implementations of several pillars of constructivist pedagogy that are clustered into ten themes, which was forumalted based on a comprehensive scan of evidence-based research in learning and teaching. The ten practices are (Kuh 2008):

- First Year Seminars and Experiences
- Common Intellectual Experiences
- Learning Communities
- Writing Intensive Courses
- Collaborative Assignments and Projects
- Undergraduate Research
- Diversity/Global Learning
- Service-Based Learning and Community-Based Learning
- Internships
- Capstone Courses and Projects

Flipped Classroom

Flipped classroom (Tucker 2012; Bishop and Verleger 2013) is a "fancy" name of a pretty much learner-centric experiential constructivist pedagogy, which is normally digitally enriched via videos and other learning technologies. The core of "flipped classroom" philosophy is rearrangement of time spent on learning in and out of classroom in which it shifts learning responsibilities toward students for a significant extent. In the "flipped classroom" approach, the expertise of the instructor is utilized more effectively in the valuable time of the classroom on guiding higher cognitive and more active and problem-/project-/experiential-based learning activities. Flipped classroom is normally characterized with pre-, in-, and post-classroom learning experiences. In recent study, 29% of faculty in the USA reported utilizing flipped classroom approaches. Emerging research and impact evaluation of the approach suggest significant improvement in learning outcomes and retention as compared to traditional teaching.

Research-Based Learning

Research-informed/research-based learning (Shaban and Abdulwahed 2012) and/or undergraduate research (UR) in the curriculum is increasingly an embraced trend. The central focus of research-based learning is on the development of the learners as independent researchers. This teaching approach is designed to promote, among the learners, a commitment to making a difference in the world through intellectual inquiry and creative expression leading to useful and innovative solutions for real-life problems. RBL assists the learners in exploring how to develop their research skills and to conduct research activities under the supervision of faculty members. Learners are encouraged to engage in real-life problem-solving, liberate their thinking, develop their writing and presentation skills, and gain confidence in their intellectual abilities.

Many benefits of RBL/UR have been enumerated in the literature. Utilizing RBL/UR may lead to enhance students' perception and interest in STEM careers, as well as to increase confidence and self-capacity to learn; learning outcomes; management, communication, and organizational skills; motivation and enthusiasm; likelihood to pursue graduate studies and development of leadership skills; and academic GPA (Bahr et al. 2006). Students who participate actively in rigorous research experience, which may involve authoring research papers, attending a conference, and/or mentoring other students, are the most likely to experience positive outcomes.

Service-Based Learning

Service-based learning is a teaching method that combines academic coursework with the application of institutional resources (e.g., knowledge and expertise of students, faculty, and staff, political position, buildings, and land) to address challenges facing communities through collaboration with these communities. This pedagogy focuses on critical, reflective thinking to develop students' academic skills, sense of civic responsibility, and commitment to the community (Definition by Centre for Civic Engagement, Michigan State University); this definition is shown in Fig. 12.2.

Service-based learning engages students in a three-part process: classroom preparation through explanation and analysis of theories and ideas; service activity that emerges from and informs classroom context; and structured reflection tying service experience back to specific learning goals. Service-based learning is a mutually beneficial endeavor in which course learning objectives are met by addressing community-identified needs "through linking academics to the community…(and) develop(ing) the skills, sensitivities and commitments necessary for effective citizenship in a democracy."

Other Pedagogies and Models

There are quite few other pedagogies and models that enable learner-centric education and can serve as a framework for developing and executing industry-integrated engineering education; we enumerate some of these below:

- Design-Based Education (Abdulwahed and Hasna 2017)
- CDIO Approach from MIT (Conceive, Design, Implement, Operate) (Berggren et al. 2003)
- DACUM Framework for Workplace Competencies Implementation (DeOnna 2002)
- Engineering Executive Education and Professional Development Courses (Berkeley 2019)
- Problem-/Project-Based Learning (Abdulwahed et al. 2009)
- Entrepreneurial Learning (Abdulwahed et al. 2013)

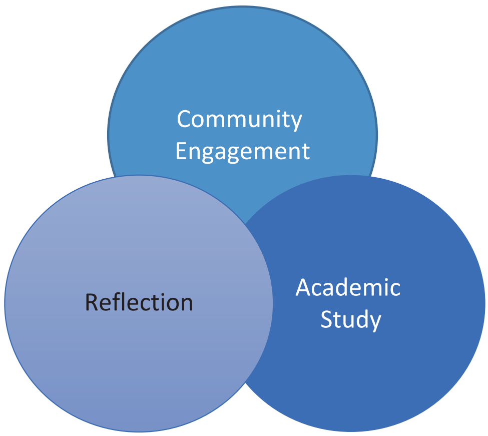

Fig. 12.2 Conceptual model of a service-based learning, which combines community engagement, academic study, and reflections

- Engineering Leadership Learning (Abdulwahed and Hasna 2016)
- Cooperative Education (Linn et al. 2004)
- EngD (Engineering Doctorate) Conducted in Industry (Kerr and Ivey 2003)

Pedagogical and Curricular Models from the Book Chapters Global Cases

One of the major aims of this book has been to provide engineering academics and schools with global perspectives on advances and cases of implementing industry-integrated engineering education from different parts of the world; in this section, we provide a brief summary for some of the pedagogical and curricular models presented in various chapters throughout the book:

Engineering MSc for Engineering Professionals (Denmark): Bente (Chap. 4, this volume) provided a case of implementation of a part-time MSc program in Denmark for professional engineers to upgrade their skills. The program is designed using project-based learning for problems in the professional context as a core component.

Integrated Model for IT Workforce-Ready Graduates (Thailand): Siddo et al. (Chap. 9, this volume) provided a study on the development of an integrated model for preparing IT graduates in Thailand for the workplace needs. The model takes into consideration influencing factors, development activities, and the IT worker's learning stages and can be implemented in IT education.

Onboarding Programs for Early-Career Engineers in Practice (USA): Babajide and Al Yagoub (Chap. 6, this volume) provided analysis of onboarding programs in the USA and provided key factor requirement of structure; these programs are utilized also as leadership development platform.

Professional Ethics for Engineering Education (USA): Winn et al. (Chap. 8, this volume) provided a well-rounded professional ethics model development in engineering education in the USA that integrates theory, philosophy, behavioral value, experiential learning, and professional ethics frameworks.

Industry-Integrated Introductory Engineering Course with Sustainability Theme (Malaysia): Yusof et al. (Chap. 3, this volume) provided collaborative design and delivery models for implementing industry in introductory engineering course through focus on sustainability.

Reverse Engineering Design for Industry-Integrated Engineering Course (Mexico): Lopez et al. (Chap. 7, this volume) provided models for implementing reverse engineering design in engineering course in Mexico together with model and procedures for delivery of the course; project-based learning (PBL) was a core component in the pedagogy delivery.

Theoretical and Empirical Framework for Design of Industry-Integrated Program (France and Qatar): Veillard et al. (Chap. 10, this volume) provided theoretical framework derived from the sociology of curriculum theory for development of industry-integrated programs, with overview models for proposed MSc program in Qatar and also overview model of existing undergraduate program in France.

Industry-Integrated Cybersecurity Needs in Graduate Certificate in Building Information Modelling (Qatar): Hammi and Bouras (Chap. 5, this volume) provided model for implementing graduate certificate in BIM with cybersecurity component based on industry needs.

Holistic Model for Industry-Integrated Cybersecurity Curriculum (France): El Melhem et al. (Chap. 11, this volume) provided a holistic approach for designing interdisciplinary cybersecurity curriculum in France in line with global and EU frameworks and best practice models.

Conclusions

Industry-integrated engineering education is an ever-emerging field and is increasingly becoming of high priority and demand by the industry. There are several advantages of effective integration of engineering education with industry needs, such as better employability of graduates, enhanced motivation of engineering students, better linkage between academic professors and industry, reduced expenditure on training in onboarding programs for early career engineers and recent engineering graduates, etc. In this chapter, we provided a toolkit of pedagogies, models, and frameworks for engineering academics to implement industry-integrated engineering education. In particular, we focused on competency-based education as one of the most suitable frameworks for holistic integration of industry in engineering education for its triangulation approach of knowledge, value/behavior, and skills/abilities. Furthermore, we demonstrated some of the learner-centric pedagogies that can be utilized for delivery and execution of industry-integrated engineering education, and finally we summarized the different models and conceptual frameworks of industry-integrated engineering education detailed in the various chapters of the book from different parts of the world.

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