SHIBAURA INSTITUTE OF TECHNOLOGY

Surveys and analyses of professional engineering competencies for education fit for the future

by

Khwanruethai Rawboon

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Abstract

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The rapid advances in a range of technology, globalization, the fourth industrial revolution, employability, and sustainability, are the major challenges for engineering education. These challenges will require new types of engineering programs, to help students develop skills in cross-disciplinarily, complexity, and contextual understanding. Future engineering students should be able to understand the needs for technological solutions in context, with sustainable solutions, be able to act in complex situations with the appropriate skills and competencies.

Professional competencies are growing critical, particularly in engineering education, due to constant progress in multidisciplinary and globalization. The need to include professional competencies in the engineering curriculum is currently a challenge for curriculum designers. The universities should adjust the educational goals of undergraduate programs to address some of the professional competencies, including using PBL and co-curricular and extracurricular activities or utilizing dedicated courses with the belief that specific courses on professional competencies may help students improve their required competencies for their future career.

Universities have faced challenges in preparing students who are competitive both in the domestic and global labor markets. This places new demands on the context, structure, and content of curriculums and educational materials and the need to explore various aspects of the social dimension and sustainability. Second, as the labor market needs ever more specific technical skills, but it is also increasingly becoming in need of professional skills. The development of professional skills in

higher education students can be considered a key factor to ensure an effective transition from higher education into the labor market.

However, engineering education around the world is confronted with the question that how they can improve the engineering education system more effectively and how to prepare engineering students for the jobs of the future?

Therefore, this dissertation provides the contributions to engineering education with the following strategies for preparing engineering students and education systems fit for the future;

1) Surveys on the needs competencies/skills for an engineering graduate to excel both in the domestic and global labor markets and diversity challenges for preparing engineering students and education systems fit for the future. The study investigated the importance of global competencies and skills, provided by Warnick, from the perspective of well-known Thai and multinational companies based in Thailand. The findings indicated that global competency is an important requirement for global engineer employment. Following that, the set of global competencies was verified to be the most critical competencies for engineers to develop based on higher education institutions' perspectives. After that, the study determined the future competencies for three demanding careers, and the findings indicated a broad mix of needed competencies in the present Industry 4.0 environment.

2) Survey on the competency of engineers working at global companies in Thailand to illustrate the gap between the competency expected for engineers by companies and the competency of working engineers measured by PROG test. The findings highlight the essential generic competencies for preparing engineering students for professional engineering employment and career success.

3) Identify an integrated learning strategy for building professional competency in engineering education to bridge the gap between engineering education and professional practice. The study found that using STEAM-PBL in engineering has a beneficial impact on students, making learning more engaging. Students have also been able to acquire a variety of skills and competencies.

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Chapter 1

Introduction

This chapter introduces the overall of the study, which includes the overall discussion on the ideas that led to this study which entitle "Surveys and analyses of professional engineering competencies for education fit for the future". The main objectives and contributions are described to clearly outline the scope of this study. Finally, the organization of this dissertation is presented.

1.1 Statement of problem and purpose

Engineering education around the world is being challenged by the impact of rapid advances in a range of technology, globalization, the fourth industrial revolution, employability, and sustainability. These challenges have affected the nature of professional engineering work and the implications for education programs. Engineers of the future will require greater abilities to find and define problems before creating solutions. Problem definition and solution will require a deeper ability to communicate and empathize with a broader range of stakeholders than what has been recognized in the past. A greater focus on the human dimensions of engineering work and increasing complexity is also anticipated. Hence, expanding the diversity of professional engineering work and expectations of graduates will require a greater diversity of competencies, educational outcomes, programs, and career pathways.

It is acknowledged that the importance for engineering students to acquire and learn to apply theoretical knowledge to real problems is a critical concern. Authentic problems help students understand the range of industrial and societal practices they will encounter. In the development of an education program, based on an integrated, hybrid learning approach, the curriculum has to integrate or combine the various challenges with already existing development trends, such as teaching and learning approach, contextual and practice experiences, professional skills, and competencies, and digital tools [Hardgraft & Kolmos, 2020].

Since the beginning of this century, competency-based approaches have been promoted in several studies that emphasize the benefits of global instruction. The engineering curriculum must be designed to provide students with the solid fundamental knowledge and to teach them how to learn. It is more important to have a curriculum that integrates knowledge and competencies to be applied in new situations.

Professional competencies are growing critical, particularly in engineering education, due to constant progress in multidisciplinary and globalization. The need to include professional competencies in the engineering curriculum is currently a challenge for curriculum designers. The universities should adjust the educational goals of undergraduate programs to address some of the professional competencies, including the use of PBL and co-curricular and extracurricular activities or utilizing dedicated courses with the belief that specific courses on professional competencies may help students to improve their required competencies for their future career.

Moreover, universities as institutions of higher education are critically considered concerning delivering education for sustainable development by raising awareness and providing the necessary competencies to cope with complex problems such as sustainable development through effective forms of higher and continuing education as well as training.

However, universities have faced challenges related to the preparation of the future engineering workforce. The first challenge is to prepare students who are competitive both in the domestic and global labor markets. This places new demands on the context, structure, and content of curriculums and educational materials and the need to explore various aspects of the social dimension and sustainability. Particularly, partnerships with the community and industry will help engineering educators reform engineering education with practical information, knowledge applicable, and competencies suitable for a diverse environment. Hence, the need to tailor an engineering curriculum with the requests coming from the labor market and the necessity to explore various aspects of the social dimension and sustainability is one of the strategic actions for university curricula development. Second, as the labor market needs ever more specific technical skills, but it is also increasingly becoming in need of professional skills. The development of professional skills in higher education students can be considered a key factor to ensure an effective transition from higher education into the labor market. Nonetheless, while technical skills are visible in many academic curricula, the character and formation of soft skills still need to be examined and highlighted among academics and students. Therefore, designing engineering programs in universities for enabling better inclusion of professional skills into the changing labor markets needs to be discussed.

Nonetheless, there is a lack of research identifying the critical professional engineering competencies from industry and academic viewpoints for preparing engineering students and Thai engineering programs for the future.

This dissertation aims to address the demands for a skilled workforce by identifying the needed competencies/skills for excel both in the domestic and global labor markets and diversity challenge for preparing their students and education systems fit for the future and bridge the gap between engineering education and professional practice by identifying an integrative learning approach for fostering professional competency in engineering education.

1.2 Research questions

Research questions 1: What are the professional engineering competencies that are required to prepare engineering students for their future?

a. Is global competency an important consideration for global engineering jobs in multinational companies in Thailand?
b. Is there a mismatch between academic perspectives and engineering industry expectations regarding the importance of global competencies in engineering education?
c. What are the future competencies for three high-skilled jobs in Industry 4.0: robotics engineers, data scientists, and food designers?
d. What are the key generic competencies for preparing engineering students for professional engineering work and career success?

Research questions 2: What is the most effective integrated learning approach for achieving professional competency in engineering education?

1.3 Structure of this dissertation

This dissertation is composed of two parts, as shown in Figure 1.1, the first part discusses the needed competencies/skills for engineering graduates and the diversity challenge for preparing students and education systems fit for the future. Chapter 2 discusses the literature review of related studies in engineering education and the essential competency aspects. Next, Chapter 3 investigates the importance of global competencies and skills required from engineering graduates from the perspective of well-known Thai and multinational companies based in Thailand. Chapter 4, investigates the perceptions of higher education institutions concerning the importance of the vital global competencies comparing with the perspective of the industry and also examines the mismatch between the two potential groups. Chapter 5 identifies the future competencies for three demanding careers representative of the high-skilled requirements of Industry 4.0: robotics engineers, data scientists, and food designers. Chapter 6 measures the generic competency of Thai working engineers, as a recent graduate, by utilizing the Progress Report on Generic Skills (PROG) assessment tool to assess their current competency and to analyze the key factors of Thai engineers' competency development in their careers. The results of this study provide guidelines for future work on the development and assessment of generic skills within the education of future engineering professionals.

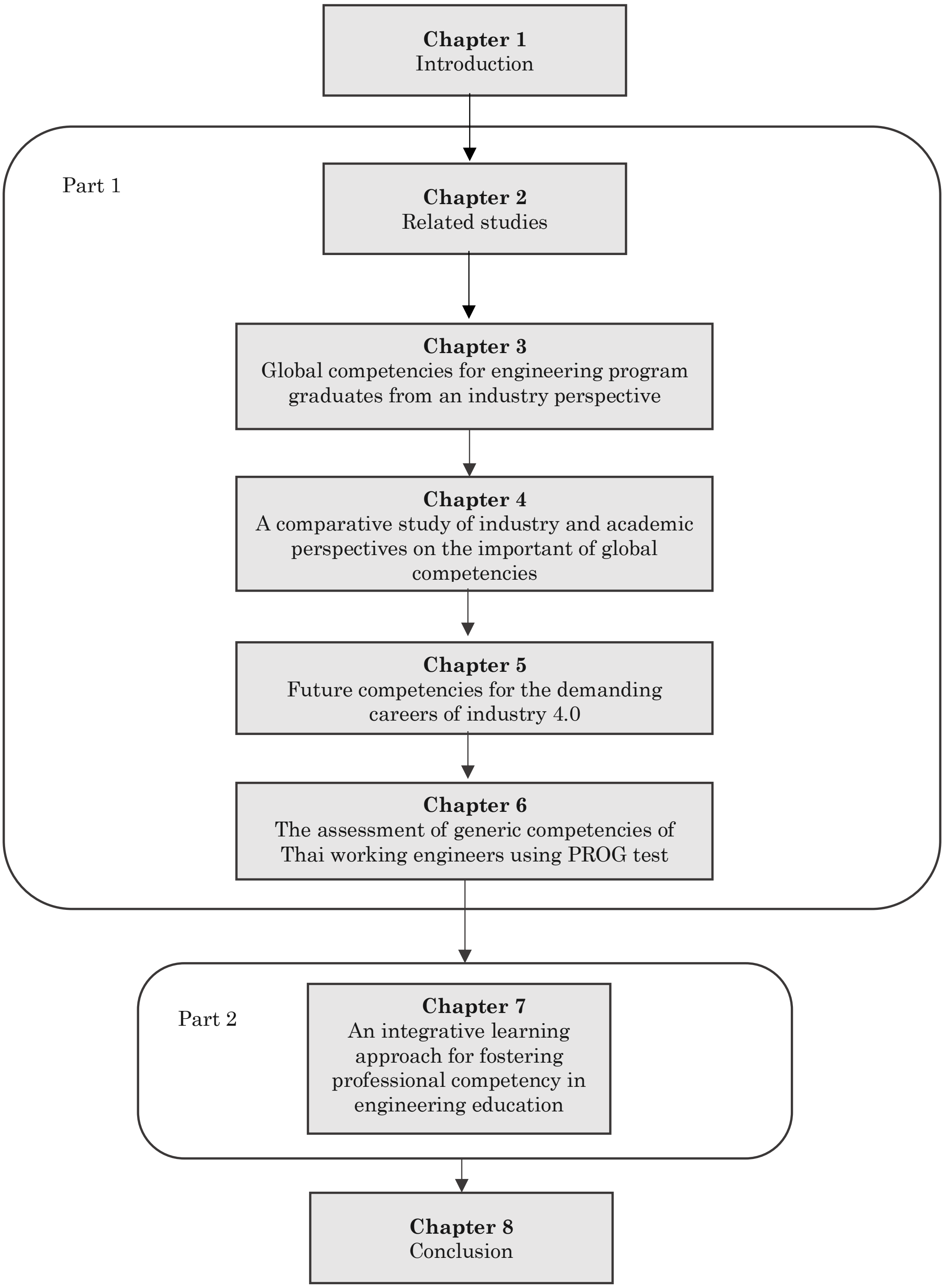

Figure 1.1 Structure of this dissertation

In the second part, chapter 7 examines the use of an integrative learning approach, which is called STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education, and presents a STEAM-PBL framework with three interrelated dimensions: (1) the learning approach, (2) the social approach, and (3) the content approach. This chapter also presents some examples of engineering programs in two Asian universities, King Mongkut's University of Technology Thonburi (KMUTT) in Thailand and Shibaura Institute of Technology (SIT) in Japan, where the professional skills and competencies of students are developed through an integrative learning approach which university-industry collaborations model and various pedagogies that have the potential to support the delivery of the T-shaped engineering graduate and the greater breadth of graduate outcomes that will be required in future.

Finally, chapter 8 concludes the study along with the discussion regarding future works opportunity of this study.

Chapter 2

Related Studies

2.1 The challenge of engineering education

Engineering education faces three major challenges that impact its future. The first challenge is sustainability. For the 17 Sustainable Development Goals (SDGs) formulated by the UN, the engineering profession is central to achieving sustainable development [UNESCO, 2017]. Society demands that engineers be able to co-creating sustainable development.

The second challenge is the fourth industrial revolution which is posed by the industry demand, involving widespread integration of technologies such as automation, artificial intelligence (AI), the Internet of Things (IoT), additive manufacturing, advanced material, and so on. This challenge demands engineers to have a set of skills in project management and the ability to learn and adapt quickly, to handle the fourth industrial revolution. Both the SDGs and industry 4.0 have re-strengthened the need for interdisciplinarity as a set of key skills, including systems thinking and design thinking. Empowerment and human values are also key elements in future development.

The third challenge is the employability and innovation competencies, posed by the gap between engineering education and work readiness. The integration of engineering education and professional practice with industry through diverse approaches such as problem/project-based learning will be the solutions to help students acquire specific skills needed for their future employment.

These three challenges call for increased emphasis on the integration of societal context and interdisciplinary, combined with professional competencies and generic skills.

In today's education, identifying the specific competencies and skills that can develop students and fulfill the demands of the employers is crucial. Also, engineering graduates usually face many challenges in many aspects of their jobs and lives, so proper engineering education is crucial to provide them with the necessary competencies for an interdisciplinary workplace [Martin et al., 2005].

Also, many universities are consequently confronted with questions concerning the future employability of their graduates and how they can prepare graduates for the workplace. Engineering graduates today are thus expected to be equipped with not only a whole set of technical skills to keep pace with rapid technology developments but also with various competencies so that they are able to meet the expanding responsibilities of their professions.

Since universities play a significant role in producing graduates who are absorbed by their relevant industries, gaining insights into the expectations of these industries when it comes to the students' competencies seems important and necessary. However, a comparative perspective of the universities and the industries can seldom provide the universities with the necessary solutions, but it can still help them provide valuable multiple perspectives that can facilitate the identification of the essential competencies so as to improve the existing curriculums.

2.2 The twenty-first century engineering education

The statement "education for the twenty-first century" signifies that nowadays, people live in a rapidly changing era in an increasingly globalized environment. Educational systems must adapt to these rapid changes, not just through one-off reforms, but on a continuous basis. The urgent need for graduates to develop professional competencies and skills is increasingly evident. Globalization has enabled greater connectivity among people from different cultures and backgrounds. It has also increased cross-border economic activity and labor force mobility, as evidenced by Wolf [Wolf, 2014]. However, many researchers have cited that a large number of higher education graduates are not well-prepared to work in a global environment. International engineers must be able to adjust to new environments, work in multicultural teams, and speak multiple languages. Therefore, a re-examination and updating of the engineering curriculum in light of societal changes and challenges is required.

The Engineering Criteria 2000—the accreditation criteria established by the Accreditation Board for Engineering and Technology (ABET)—emphasize the need to prepare graduates for successful entry and long-term careers in engineering. It is the responsibility of the institutions and higher education to satisfy these criteria. The ABET states that all engineering baccalaureate graduates should possess a set of 11 outcomes, according to Criterion 3. These outcomes can be divided into two categories: five "hard" technical skills and six "professional" skills [Shuman et al., 2005]. In addition to these skills, the new engineering criteria should focus on the essential global skills that help engineering professionals work in multicultural and global environments. Recent studies in engineering education also emphasize that engineering graduates should possess a set of competencies and skills necessary for their professional careers in industry, in addition to fundamental knowledge in mathematics, science, and engineering theory [Esparragoza et al, 2016]. Therefore, the participation of industry professionals in engineering education must be an integral part of the engineering curriculum.

2.3 Professional Engineering Competency

According to recent studies, engineering education is continuously evolving [National Academy of Engineering, 2004; Conlon, 2008]. Industrial leaders and multinational companies are looking for engineering graduates who have professional skill sets. However, various studies have indicated that engineering graduates tend to have poor professional skills and do not have the required ability to work with people from different backgrounds [Wellington et al, 2002].

The Accreditation Board for Engineering and Technology (ABET) states that all engineering baccalaureate graduates should possess a set of 11 outcomes according to Criterion 3. These outcomes can be divided into two categories: five "hard" technical skills and six "professional" skills [Shuman, 2005].

In addition to the essential "hard" and "professional" skills, new engineering criteria should focus on essential global skills that can help engineering professionals work in multicultural and global environments.

2.4 Global competency in engineering education

Generally, global competence can improve organizational and individual effectiveness in learning and career success at a multinational workplace. Moreover, awareness of international communication-related knowledge and skills is considered to guarantee career success in a global context. In the globally integrated labor market, striving to achieve global competence can ensure organizational and individual competitiveness and effectiveness. Therefore, it seems plausible to encourage students to utilize their global competence to cope with different issues in response to different foreign tasks. Many studies have argued that engineers should develop global competence. While the term "global competence" has been used extensively, its meaning is not very apparent.

Based on literature analysis, a good summary of definitions of global competence is provided by Warnick [Warnick, 2010]. In his survey, Warnick summarized critical elements of global competence in engineering and provided appropriate supporting evidence from the literature as follows:

1) Exhibit a global mindset – the ability of individuals to establish self-awareness, understand culture norms and expectations, and realize that they are part of a global world;

2) Appreciate and understand different cultures – a developed awareness, appreciation, and understanding of, as well as adaptability to diverse cultures, perceptions, and approaches with an ability to interact with people from other cultures and countries;

3) Demonstrate world and local knowledge – an ability to understand the major currents of global change and its implications, and demonstrate knowledge within a global and comparative context;

4) Communicate cross-culturally – an ability to interact with and understand people from different cultures and recognize the importance of both appropriate verbal and nonverbal communication, including the ability to communicate and interact in a globally interdependent world;

5) Speak more than one language including English – an ability to communicate in the international business language of English both orally and in writing, and the ability to speak another language;

6) Understand international business, law, and technical elements – an ability to understand the different cultural contexts of how business, law, engineering, and technology might be approached and applied, and the implications of each within an international environment;

7) Live and work in a transnational engineering environment – an ability and awareness to live and work effectively in international settings;

8) Work in international teams – an ability to collaborate and contribute to multicultural work environments either in person or in geographically distributed teams with people of different cultures and linguistic backgrounds, where diverse ways of thinking, being, and doing are the basis of practice.

In this context, various lists of necessary skills have been developed for professional engineers. According to the ABET Criterion 3, the following technical competencies are essential for engineers:

1) An ability to apply knowledge of mathematics, science, and engineering;

2) An ability to design and conduct experiments, as well as to analyze and interpret data;

3) An ability to design a system, component, or process to meet desired needs within realistic constrains such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

4) An ability to identify, formulate, and solve engineering problems;

5) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Moreover, Grade Point Average (GPA) and work experience are considered to be essential elements for sorting and assessing candidates for employment in today's workplace as follows:

1) A high GPA;

2) Pertinent applicable work experience.

However, many studies have reported that there is a mismatch between the graduate students' skills developed during their course studies and the essential skills required in a global workplace [Nicolescu & Paun, 2009; Hernández-March et al., 2009; Koppi et al., 2009].

2.5 The Industry perspective of global competencies

In higher technical education systems, the industry is considered as an external customer, whereas students are considered internal customers. It is essential to understand the perspective of industry executives regarding the skills required from engineering graduates. Recently, many engineering organizations have emphasized the importance of global engineering competencies and skills for engineering program graduates. Mohammad [Mohammad, 2004] pointed out that excellent academic degrees alone are inadequate; employers require professional engineers to have competencies and professional skills because globalization demands companies to be competitive in their management systems. Morell [Morell & Trucco, 2012] also highlighted the impact of engineering education on a knowledge-based economy from an industry perspective. His research noted that the industry had been involved in a process of engineering curriculum innovation to make it more suitable to its needs. In this way, the integration of engineering professional skills and an awareness of business constraints through practice-based projects with real industry issues can be achieved.

Multinational companies seek engineering graduates able to work in multinational teams, which cross-temporal, geographical, and disciplinary boundaries [Levonisova, et al., 2015]. The industry also seeks graduates, who can collaborate within a diverse culture workforce, and who possess in-depth expertise within a single domain [Agrawal & Harrington-Hurd, 2016]. However, recent research has revealed that the skills and competencies of university graduates are not aligned with the needs of the industry sectors [Nicolescu and Paun, 2008; Hernández-March et al., 2009; Koppi et al., 2009]. There is a wide gap between industry requirements and graduates' ability to meet these requirements [Almi et al., 2011]. Many researchers have worked to expand the knowledge concerning global competencies and their importance to engineers. Nowadays, the development of global competences and skills has become essential for engineers to allow them to participate professionally in a multinational environment. Parkinson [Parkinson, 2009] proposed 13 dimensions of global competence and surveyed results from engineering educators and industry leaders regarding the importance of these dimensions. The five most influential global competency attributes for engineers were: (1) ability to appreciate other cultures; (2) proficiency to work in or direct a team of ethnic and cultural diversity; (3) ability to communicate across cultures; (4) chance to practice engineering in a global context; and (5) effective dealing with ethical issues arising from cultural or national differences. Warnick [Warnick, 2011] conducted research to determine whether multinational companies consider global competence a critical skill for mechanical engineering graduates when making hiring decisions, and the implications for higher education engineering programs. His research focused on evaluating standard hiring technical engineering competencies with respect to eight global competencies. The top global competencies valued by employers were the ability to communicate cross-culturally, followed by an appreciation and understanding of different cultures, and the ability to work in international teams. According to the authors' findings, it is crucial that engineering graduates' competencies match the features and qualities demanded by the industry.

Chapter 3

Global Competencies for Engineering Program Graduates from An Industry Perspective

3.1 Background and purpose of the study

Nowadays, people live in an era of globalization, in which the world is enormously interconnected and interdependent. These new developments have resulted in an increase in the frequency of interaction among people of diverse cultural and ethnic backgrounds. They have also resulted in a rise in international trade and investment, growing transnational communications, and an expansion of cross-border alliances for businesses and industries.

The role of education has expanded from a local to a global level in the twenty-first century. Nowadays, education plays a significant role in connecting students with the global community and raising awareness about global issues. This means that universities must prepare their students to join a globalized workforce by enhancing students' global competency levels [Fantini et al., 2001; DiBenedetto and Myers, 2016; UNESCO, 2015; Chu et al., 2017]. Global competency has been increasingly acknowledged as an essential prerequisite for newly graduated engineering students preparing to join multinational companies [EL-Sakran and Awad, 2012; Streiner, 2015]. It is also regarded as a core skill that all students must acquire [Fantini et al., 2001]. In particular, global collaborative environments in the corporate world require engineers with global professional competencies and skills. The need to identify and assess these competencies and skills has been the focus of industry leaders [Bourn and Neal, 2008] and is an essential undertaking for organizations operating in a global context.

For this reason, it is crucial for educators in engineering education programs to provide high-quality, targeted engineering education that encompasses the technical engineering skills and global competencies required by the industry [Male, 2010]. Moreover, as engineering education is required by both the industry and society as a whole, it is essential to consider the requirements and expectations for successfully integrating all the necessary skills and competencies into the undergraduate engineering curriculum.

The purpose of this study was to assess the importance of global competencies and skills required from engineering graduates wishing to work globally from the perspective of well-known Thai and multinational companies based in Thailand. The results of this study are expected to help engineering departments at universities in Thailand, Japan, and other countries enhance their current engineering curriculum.

3.2 Research question

Research Question 1a: Is global competency an important consideration for employment in multinational companies in Thailand?

Specifically, the objectives of this study are:

1. To identify crucial global competencies and skills through an in-depth literature review;

2. To investigate the perceptions of well-known Thai and multinational companies with respect to the importance of these global competencies and skills;

3. To compare the necessary skills and competencies required from engineering professionals among three group countries.

3.3 Methodology

The goal of this research was to evaluate the relevance of global competencies and abilities required of engineering graduates who want to work worldwide from the perspective of well-known Thai and multinational organizations in Thailand. However, there is a shortage of industry research on how multinational companies view global competencies in comparison to traditional technical skills.

For this reason, an investigation based on multinational company respondents has been developed to help encourage discussion on how professional engineers view engineering global competencies and skills. We investigated well-known Thai and multinational company perceptions regarding the importance of these vital global competencies for Thai and Japanese engineering students wishing to work globally by asking the question: "how important is it for engineering students wishing to work globally to possess each of the listed global competence items?" We created a Thai version of the competence items required from technical personnel in Warnick's survey with the permission of Dr. Gregg Warnick. Based on the "hard" technical skills section in the ABET Criterion 3 shown in Table 3.1, we identified 15 competencies. These include eight global competencies and five technical engineering competencies. For comparison, GPA and work experience were also included.

The survey was designed to determine and prioritize the competencies and skills, which are desired and valued by well-known Thai, Japanese, and other multinational companies.

The survey contained questions related to employment (job title, industry type, and headquarters location) and global competencies (skills to be rated on a Likert scale). For the global competences section, the respondents were asked to rate the importance of and their satisfaction with each of the following competence item:

1) Not Important;

2) Not Very Important;

3) Quite Important;

4) Very Important;

5) Extremely Important.

The survey was distributed among the alumni of a Thai university engineering program, which included employees from well-known Thai companies (such as CPF, TTCL, TKK, and GFPT), Japanese companies (such as Yamaha, Nissan, Sony, and Sumitomo), and other multinational companies (such as Delta, Baxter, and BIGL).

Table 3.1 Engineering global competency items and definitions

Competency	Definition
Exhibit a global mindset	Self-awareness, understanding of cultural norms and expectations, and appreciation of being part of a global world
Appreciate and understand different cultures	Developed awareness, appreciation, understanding of and adaptability to diverse cultures, perceptions, and approaches, as well as ability to interact with people from other cultures and countries
Demonstrate world and local knowledge	Understanding of the major trends in global change and their implications, and demonstrative knowledge of the global and comparative context
Communicate cross-culturally	Ability to interact with and understand people from different cultures and recognize the importance of appropriate verbal and nonverbal communication, including the ability to communicate and interact in a globally interdependent world
Speak more than one language including English	Ability to communicate in the international business language of English both verbally and in writing, and ability to speak another language
Understand international business, law, and technical environment	Understanding of different cultural contexts on how business, law, engineering, and technology can be approached and applied, and their implications within an international environment
Live and work in a transnational engineering environment	Ability to live and work effectively in international settings

Work in international teams	Collaborative approach and ability to contribute professionalism in multicultural work environments either in person or in geographically distributed teams with people of different cultures and linguistic backgrounds, where diverse ways of thinking, being, and doing are the basis of practice
Apply knowledge of mathematics, science and engineering	The ABET 2000 Criterion 3 Student outcome A
Design and conduct experiments, as well as to analyze and interpret data	The ABET 2000 Criterion 3 Student outcome B
Design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, health and safety, manufacturability, and sustainability	The ABET 2000 Criterion 3 Student outcome C
Identify, formulate, and solve engineering problems	The ABET 2000 Criterion 3 Student outcome E
Use the techniques, skills, and modern engineering tools necessary for engineering environment	The ABET 2000 Criterion 3 Student outcome K
A high-grade point average (GPA)	Grade point average; an indication of a student's academic achievement at university
Pertinent applicable work experience	Work experience is considered an essential element for sorting and assessing candidates

The survey was conducted from February to March 2019. It was addressed to individuals in managerial positions in the technical division of their respective companies. One-hundred and sixteen engineering employees participated in this survey.

3.4 Analysis and results

The survey respondents provided information regarding their age, education level, employment period, job title, industry type, and their company's nationality and a number of employees.

The majority (59%) of the respondents were in the 30–39 age group, 25% were in the 20–29 age group, 12% were in the 40–49 age group, 3% were in the 50–59 age group, and 1% were in the 60 or over age group, as shown in Table 3.2.

Table 3.2 Age groups of the survey respondents

Age group	Responses	Percentage
20–29 years	29	25
30–39 years	69	59
40–49 years	14	12
50–59 years	3	3
60 or over	1	1
Total	116	100

The survey respondents were asked to provide their education degrees. The majority (61%) of the respondents had completed a bachelor's degree, 34% had completed a master's degree, 2% had completed an associate's degree and high-school certificate, and 1% had a doctoral or professional degree, as indicated in Table 3.3.

Table 3.3 Education degrees of the survey respondents

Education Degree	Responses	Percentage
High-school graduate	2	2
Associate’s degree	2	2
Bachelor's degree	71	61
Master’s degree	40	34
Doctoral or Professional degree	1	1
Total	116	100

The survey respondents were asked to provide their employment period. At the time of the survey, the majority (60%) of the respondents had been employed by a company for 1–5 years, 26% had been employed for 6–10 years, 10% had been employed for 11–20 years, 3% had been employed for 21–30 years, and 1% had been employed more than 30 years, as shown in Table 3.4.

Table 3.4 Employment period of the survey respondents

Employment Level	Responses	Percentage
1–5 years	70	60
6–10 years	30	26
11–20 years	12	10
21–30 years	3	3
Over 30 years	1	1
Total	116	100

The survey respondents also provided their job titles. At the time of the survey, the majority (56%) of the respondents worked as engineers, 13% as engineering supervisors, 12% as engineering managers, 6% as CEOs/presidents/owners, 1% as directors, and 12% in other positions, including production supervisors, technical staff, and consultants. These results are shown in Table 3.5.

Table 3.5 Job title of the survey respondents

Job Title	Responses	Percentage
CEO/President/Owner	7	6
Director	1	1
Engineering Manager	14	12
Engineering Supervisor	15	13
Engineer	65	56
Other	14	12
Total	116	100

Next, the respondents were asked to identify the type of industry that most closely matched their current employment. The top five industries were automotive (25%), other (24%), food and beverage (14%), electronics (10%), and automation and robotics (9%), as indicated in Table 3.6.

Table 3.6 Industry types of the survey respondents

Industry Type	Responses	Percentage
Automotive	29	25
Food and Beverage	16	14
Electronics	12	10
Medical Hub	3	3
Agriculture and Biotechnology	8	7
Automation and Robotics	11	9
Aviation and Logistics	2	2
Biofuels and Biochemicals	1	1
Digital	5	4
Affluent, Medical and Wellness Tourism	1	1
Other	28	24
Total	116	100

Subsequently, the survey respondents were asked to provide their company's headquarters location or company nationality. As shown in Table 3.7, the majority (61%) of the respondents worked in Thai companies, 22% worked in Japanese companies, and 17% worked in other multinational companies.

Table 3.7 Company nationality of the survey respondents

Company's nationality	Responses	Percentage
America	11	9
China	1	1
Germany	1	1

Singapore	1	1
Thailand	71	61
Japan	25	22
Other	6	5
Total	116	100

The number of employees within the respondents' companies was also included in the survey. The majority (25%) of the survey respondents worked for large companies, which employ more than 10,000 employees, 23% worked for companies with 1,000–4,999 employees, 22% worked for small companies with fewer than 100 employees, and 14% worked for companies with 100–499 employees, as shown in Table 3.8.

Table 3.8 Number of employees of the survey respondents

Number of employees	Responses	Percentage
Less than 100	25	22
100 to 499	16	14
500 to 999	8	7
1,000 to 4,999	27	23
5,000 to 10,000	11	9
More than 10,000	29	25
Total	116	100

As the purpose of this study was to assess the importance of global competencies and skills required from engineering graduates wishing to work globally from the perspective of well-known Thai and multinational companies based in Thailand. The following research questions were utilized to address this purpose:

Research Questions 1a: Is global competency an important consideration for employment in multinational companies in Thailand?

This question was answered using survey results from well-known Thai, Japanese, and multinational companies. The respondents were asked to evaluate 15 competence items in a survey, which consist of eight global and five engineering competencies from the ABET Criterion 3, in addition to GPA and work experience.

The comparison of the survey results among well-known Thai, Japanese, and multinational companies was conducted by rating 15 different competencies on a 5-point Likert scale based on the question "how important is it for engineering students wishing to work globally to possess each of the listed global competence items?" Each competence item, its average (mean) rating score, standard deviation, and the one-way analysis of variance (ANOVA) across the three groups of countries are presented in Table 3.9.

The one-way ANOVA ($\alpha = 0.05$) was performed to determine whether there are any statistically significant differences among the means of each competence item of the three country groups. As shown in Table 3.9, the P-values are larger than 0.05 and there is no significant difference among groups for all competence items. It is evident that the nationality factor does not affect the evaluation of the importance of global competencies for engineering students, since all nations of the world have entered a new era of globalization. Therefore, global competencies are considered as vital skills for living in a globalized society.

In Table 3.9, the five high-importance satisfaction items of the average value of each group are shaded. The results illustrate that all three country groups consider that both the standard engineering technical competencies from ABET Criterion 3 and global competencies are essential for engineering students wishing to work globally.

Table 3.9 Comparison of ratings of the considered competence items

	Global Competency Item	Thai (n = 71)		Japanese (n = 25)		Others (n = 20)		ANOVA	
		Mean	SD	Mean	SD	Mean	SD	F	P
1.	Ability to exhibit a global mindset	4.04	0.85	4.00	0.76	4.00	0.97	0.03	0.97
2.	Ability to appreciate and understand different cultures	3.97	0.91	4.00	0.87	3.90	1.02	0.07	0.93
3.	Ability to demonstrate world and local knowledge	3.93	0.83	3.92	0.81	3.95	0.76	0.01	0.99
4.	Ability to communicate cross-culturally	3.94	0.95	4.00	0.76	3.95	0.89	0.04	0.96
5.	Ability to speak more than one language, including English	3.99	1.02	3.96	1.14	4.20	0.89	0.39	0.68
6.	Ability to understand international business, law, and technical elements	3.68	0.87	3.68	0.63	3.65	0.88	0.01	0.99
7.	Ability to live and work in a transnational engineering environment	3.90	0.94	3.88	0.67	3.95	0.76	0.04	0.96
8.	Ability to work in international teams	4.11	0.90	4.32	0.75	4.00	0.73	0.88	0.42
9.	Ability to apply knowledge of mathematics, science and engineering	3.99	0.93	4.12	0.67	4.20	0.77	0.59	0.56
10.	Ability to design and conduct experiments, as well as to analyze and interpret data	3.97	0.89	4.16	0.69	4.10	0.85	0.53	0.59
11.	Ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, health and safety, manufacturability, and sustainability	3.83	0.83	3.92	0.76	3.75	0.91	0.24	0.79
12.	Ability to identify, formulate, and solve engineering problems	4.04	0.85	4.16	0.75	4.15	0.88	0.25	0.78
13.	Ability to use the techniques, skills, and modern engineering tools necessary for engineering environment	4.04	0.89	4.08	0.76	4.05	0.89	0.02	0.98
14.	High GPA	2.90	1.02	2.84	0.55	2.85	0.93	0.05	0.95
15.	Pertinent applicable work experience	3.72	0.93	3.64	0.91	3.55	0.89	0.28	0.75

The results show that well-known Thai companies value global competencies equally to standard engineering technical competencies. The following three out of eight global competencies are considered to be critical for engineering students by well-known Thai companies: ability to work in international teams, exhibit a global mindset, and speak more than one language, including English.

Well-known Thai companies consider that two out of five standard technical engineering competencies are substantially similar to Japanese and other multinational companies in Thailand: ability to identify, formulate, and solve engineering problems, and ability to use the techniques, skills, and modern engineering tools necessary in an engineering environment.

It is evident that well-known Thai companies tend to value global competencies because Thailand has an open market-oriented economy and encourages international direct investment as a means of promoting economic development, employment, and technology transfer.

Thailand continues to welcome international investment and seeks to avoid dependence on any specific country as a source of investment. Therefore, the country has to develop skill sets that enable employees to compete in an ever-expanding global environment. In particular, well-known Thai and Japanese companies rate the ability to work in an international team as an essential competency for engineering students.

The majority of the survey respondents from well-known Thai and Japanese companies work in the automotive and food and beverage manufacturing industries, respectively, as indicated in Figures 3.1–3.2, where the need for effective teamwork, in addition to leadership skills, is critical. As evident in Lingard's research, teamwork is recognized as an essential skill for engineering professionals [Lingard and Barkataki, 2011].

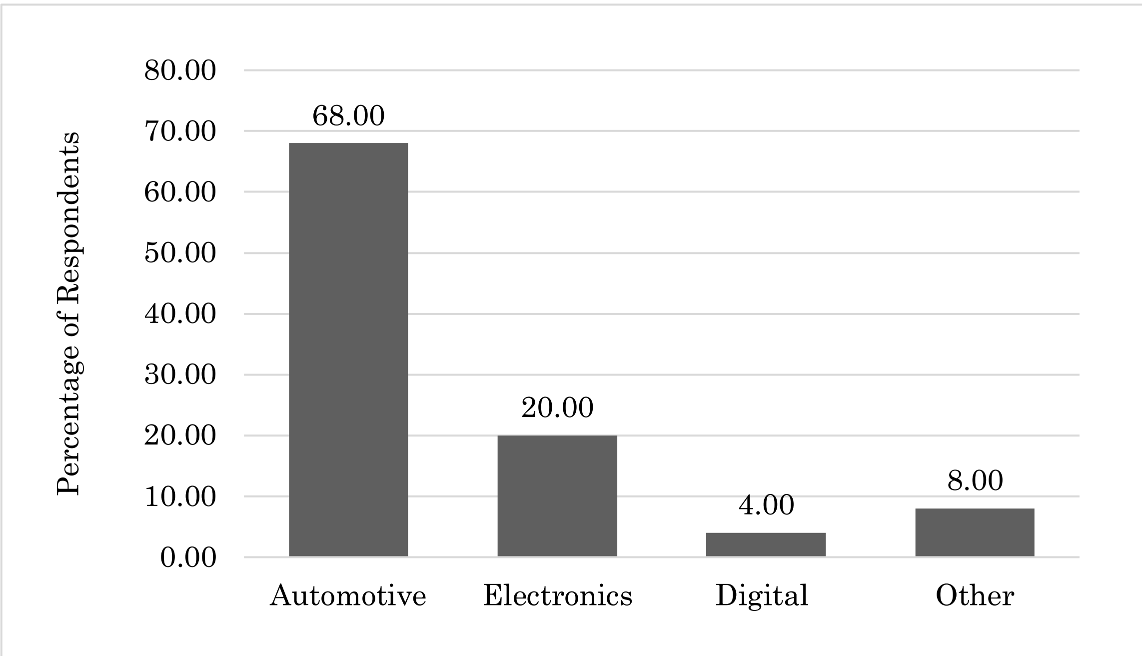

Figure 3.1 Industry type of well-known Thai companies

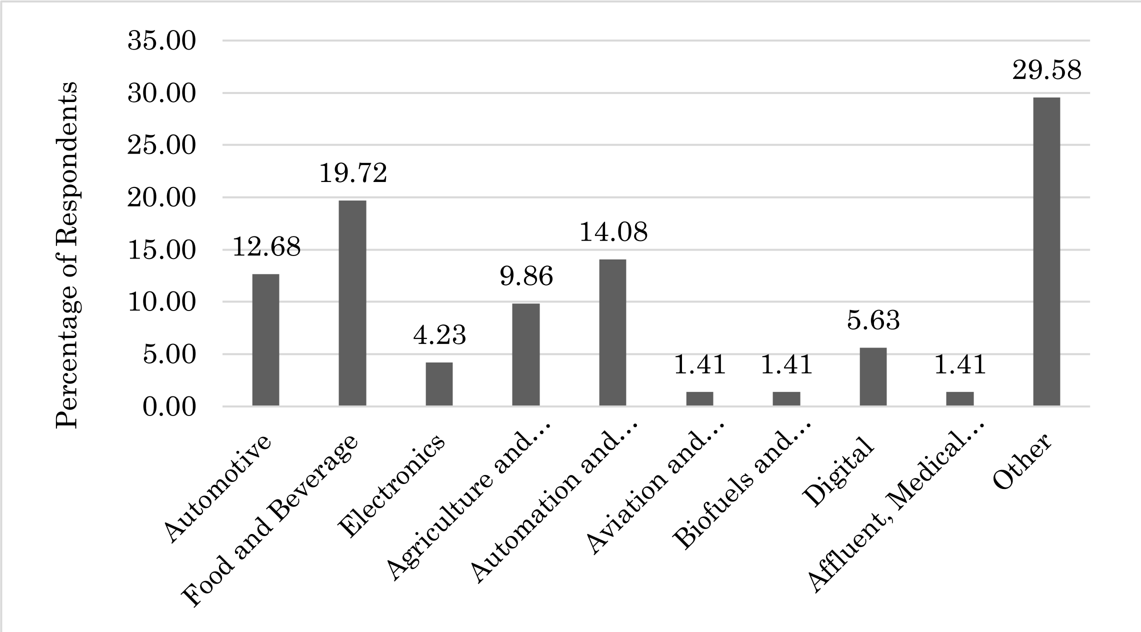

Figure 3.2 Industry type of Japanese companies

Working in an international team is a skill that can be taught and improved through practice, feedback, and experience. Active listening, being attentive to international context and stakeholders, deferring early judgment, leadership, and managing projects are crucial for those who work in multinational teams.

Furthermore, well-known Thai and other multinational companies value the ability of engineering students to speak more than one language, including English because fluency in the English language is regarded as crucial to becoming a professional global engineer.

This study also indicated that all three country groups regard the following as the most crucial core competencies, because they are useful and commonly applied in a practical industrial environment: ability to identify, formulate, and solve engineering problems; ability to use the techniques, skills, and modern engineering tools necessary for an engineering environment; ability to apply mathematics, science, and engineering.

According to all three country groups, GPA and pertinent applicable work experience are considered essential for engineering students, as previously pointed out in Warnick's and Oda's survey [Warnick, 2010; Oda et al., 2018]. However, they are not considered as necessary criteria for engineering graduates seeking to work in multinational companies in Thailand. This is because engineering graduates can acquire new knowledge related to their roles and the necessary experience once they are in the workplace.

These results indicate that standard engineering technical competencies are essential, and global competencies are vital for engineering students seeking to work in a global environment.

3.5 Conclusion

The study presented in this work highlighted the necessity of equipping engineering graduates with global competencies. In today's global context, engineers are not only required to demonstrate their technical competencies, but they must also have acceptable global competencies to excel in the international workplace. New engineering criteria in the twenty-first century education should focus on the essential global skills that can help engineering students become globally competent engineers. However, significant evidence reveals that many graduate engineers fall short of meeting these industry requirements. It is crucial to understand the perspectives of industry executives regarding the competencies required from engineering graduates.

The study was to assess the importance of global competencies and skills required from engineering graduates wishing to work globally from the perspective of well-known Thai and multinational companies based in Thailand. The following research questions were utilized to address this purpose:

Research Questions 1a: Is global competency an important consideration for employment in multinational companies in Thailand?

Fifteen different competencies were evaluated by survey respondents, which consist of eight global and five engineering competencies from the ABET Criterion 3, in addition to GPA and work experience. Survey respondents rated each competency on a five-point Likert scale based on the question "how important is it for engineering students wishing to work globally to possess each of the listed global competence items?" Each competence item, its average (mean) rating score, standard deviation, and the one-way analysis of variance (ANOVA) across the three groups of countries are presented.

The results show that possessing and showing standard engineering technical capabilities is required for employment as an engineer, whether the engineer works in an international context or not. Global competence, on the other hand, is an essential criterion for employment, and engineers should pay special attention to developing the ability to work in international teams, ability to exhibit a global mindset, and ability to speak more than one language, including English.

Therefore, preparing engineering students to be effective in a multinational workplace, engineering education systems should aim at improving engineering programs and providing an accurate systems approach to future global engineers. They should also aim at reforming the engineering curriculum to better reflect industry needs by preparing students for multicultural teamwork with the appropriate and essential global skills that will enable graduates to work in multicultural and global environments.

This study can be useful to engineering students, university faculties, and engineers with the necessary competencies to succeed in the workplace and contribute to the wider economic progress of the country.

Chapter 4

A Comparative Study of Industry and Academic Perspectives on The Important of Global Competencies for Engineering Education

4.1 Background and purpose of the study

In the past several years, engineering education increasingly focused on the necessary critical skills for new engineering graduates [Dotong et al., 2017; Wood et al., 2013]. The rapid changes in technology and the globalization of engineering education led to a greater attention to professional engineering skills. Thus, a need to include global competencies together with hard and soft competencies in educational engineering programs exists, especially since engineering graduates are now required to work within multicultural and multinational workplaces. Moreover, the necessary requirements for engineering professionals to work across different cultures and disciplines have been recognized by the National Academy of Engineering in their report on the future of engineering [National Academy of Engineering, 2004] and by the Accreditation Board for Engineering and Technology (ABET) accreditation criteria [ABET, 2016]

Generally, global competencies are increasingly acknowledged as crucial skills for newly graduated engineering students who want to join global workplaces and work in diverse national and cultural contexts [Polukhima and Doskovskaya, 2018] In addition, multinational organizations are now more selective when employing professional engineers. As such, the expectations of the skills of new candidates are now much higher than before, particularly for engineering graduates. Hence, understanding the perspectives of the industry executives who regard such skills as vital for hiring new engineering graduates is essential so as to gain insight into the perceptions of educational stakeholders.

Various studies focused on the gaps between the engineering competencies earned during academic years and those needed in engineering industries. Also, many industries noted that recent graduates exhibit competency gaps. Therefore, it is essential that new measures need to be planned to bridge such gaps in order to make engineering students more able to succeed in global markets. Thus, some collaborations between academia and engineering industries are working on practical improvements to engineering education.

The purpose of this study was to identify the gaps between academia and engineering industries by investigating the perceptions of higher education institutions when it comes to the importance of global competencies for engineering graduates who aim to work globally and then comparing them with the perspectives of multinational Thai companies in Thailand. The results of this study are expected to help the engineering departments in many universities in Thailand, Japan, and other countries to enhance their current engineering curriculum so it can match the industry requirements.

4.2 Research question

Research Question 1b: Is there a gap between academic perspectives and engineering industries' expectations on the importance of global competencies for engineering education?

Specifically, the objectives of this study are:

1. To investigate higher education institutions' perspectives on the value of global competencies for engineering graduates who do want to work globally;

2. To compare the requisite skills and competencies for engineering graduates to the viewpoints of multinational Thai companies in Thailand.

4.3 Methodology

The previous research surveyed the importance of global competencies from the perspectives of well-known Thai and multinational companies in Thailand [Rawboon et al., 2019a]. However, a lack of research from an academic perspective still exists.

For this reason, we investigated the perceptions of higher education institutions concerning the importance of these vital global competencies for Thai and Japanese engineering students who aim to work globally so as to examine the mismatch between the two potential groups by asking the following question: "How important is it for engineering students who will work globally to possess each of the listed global competency skills?" We also created a version of the required competencies from technical personnel in Warnick's survey with the permission of Dr. Gregg Warnick. Based on the "hard" technical skills section in the ABET Criterion 3, as shown in Table 4.1, we identified 15 competencies, including eight global competencies and five technical engineering competencies. For comparison purposes, we also included the grade point average (GPA) and work experience.

Table 4.1 Engineering global competency items

Set of competencies	
Global competencies	Exhibit a global mindset
	Appreciate and understand different cultures
	Demonstrate world and local knowledge
	Communicate cross-culturally
	Speak more than one language including English
	Understand international business, law, and technical Environment
	Live and work in a transnational engineering environment
	Work in international teams
Technic	Apply knowledge of mathematics, science and engineering
	Design and conduct experiments, as well as to analyze and interpret data

	Design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, health and safety, manufacturability, and sustainability
	Identify, formulate, and solve engineering problems
	Use the techniques, skills, and modern engineering tools necessary for engineering environment
Other	A high-grade point average (GPA)
	Pertinent applicable work experience

The survey comprised of questions related to personal and employment (age group, education degree, employment period, job position, and major/department) and global competencies (skills to be rated on a Likert scale). For the global competencies section, the respondents were asked to rate the importance of each competency item and their satisfaction with it as follows:

1) Not Important;
2) Not Very Important;
3) Quite Important;
4) Very Important;
5) Extremely Important.

The survey was distributed among the educational stakeholders and leaders of a Thai university engineering program. The survey was conducted from August to September 2019, and 129 engineering educational stakeholders took part in it.

4.4 Analysis and results

The survey respondents provided information concerning their age, education level, employment period, job title, and department.

The majority of the respondents (49%) were in the 40–49 age group, 31% were in the 30–39 age group, 15% were in the 50–59 age group, 4% were in the 20–29 age group, and 2% were in the 60 or over age group, as shown in Table 4.2.

Table 4.2 Age group of the survey respondents

Age Groups	Response	Percentage
20–29 years	5	4
30–39 years	40	31
40–49 years	63	49
50–59 years	19	15
60 or over	2	2
Total	129	100

The survey respondents were asked to indicate their education degree. The majority of the respondents (74%) completed a doctoral degree, and 26% completed a master's degree, as indicated in Table 4.3.

Table 4.3 Education degree of the survey respondents

Education Degree	Response	Percentage
Master's degree	34	26
Doctoral or Professional degree	95	74
Total	129	100

The survey respondents were asked to indicate their employment period. The majority of the respondents The majority of the respondents (35%) were employed in the university for 11–20 years at the time of the survey, 23% were employed for 21-30 years, 19% were employed for 1–5 years, 18% were employed for 6–10 years, and 5% were employed more than 30 years, as shown in Table 4.4.

Table 4.4 Employment period of the survey respondents

Employment Period	Response	Percentage
1–5 years	24	19
6–10 years	23	18
11–20 years	45	35
21–30 years	30	23
Over 30 years	7	5
Total	129	100

The survey respondents also included their teaching and research positions. As shown in Table 4.5, the majority of the respondents (31%) worked as lecturers at the time of the survey, 30% as engineering assistant professors, 16% as associate professors, 15% as researchers, 3% as program responsible lecturers, 2% as learning facilitator/educational developers and in other positions, including teaching assistants, and 1% as professors.

Table 4.5 Teaching and research positions of the survey respondents

Teaching and Research Position	Response	Percentage
Professor	2	1
Associate Professor	26	16
Assistant Professor	49	30
Lecturer	51	31
Researcher	24	15
Program Responsible Lecturer	5	3
Learning Facilitator/Educational Developer	4	2

Other	3	2
Total	164	100

The survey respondents also added their academic management positions. As shown in Table 4.6, the majority of the respondents (26%) worked as heads of departments at the time of the survey, 19% as vice-deans, and 16% in other positions, including instructors, curriculum committee's organizers, members of academic committees, secretaries of departments, and deputy heads of departments. Also, 11% worked as directors, 10% as vice-directors, 8% as assistants to the president, 6% as assistants to the dean, and 2% were the president and the dean.

Table 4.6 Academic management positions of the survey respondents

Academic Management Position	Response	Percentage
President	1	2
Assistant to the President	5	8
Dean	1	2
Vice-Dean	12	19
Assistant to the Dean	4	6
Director	7	11
Vice-Director	6	10
Head of Department	16	26
Other	10	16
Total	62	100

The respondents were asked to identify their major/department. The top five departments were mechanical engineering (19%), production engineering (14%), electrical engineering, civil engineering (10%), and tool and materials engineering (9%), as indicated in Table 4.7.

Table 4.7 Major/Department of the survey respondents

Major/Department	Response	Percentage
Chemical Engineering	8	6
Civil Engineering	13	10
Computer Engineering	7	5
Control Systems and Instrumentation Engineering	2	2
Electrical Engineering	14	11
Electronics and Telecommunications Engineering	7	5
Environmental Engineering	4	3
Mechanical Engineering	24	19
Production Engineering	18	14
Tool and Materials Engineering	11	9
Food Engineering	2	2
Biological Engineering	5	4
Other	14	11
Total	129	100

As the purpose of this study was to identify the gaps between academia and engineering industries by investigating the perceptions of higher education institutions when it comes to the importance of global competencies for engineering graduates who aim to work globally and then comparing them with the perspectives of multinational Thai companies in Thailand. The following research questions were utilized to address this purpose:

Research Questions 1b: Is there a gap between academic perspectives and engineering industries' expectations on the importance of global competencies for engineering education?

This question was answered using survey results from the perceptions of higher education institutions comparing them with the perspectives of multinational Thai companies in Thailand from the previous research. The respondents were asked to evaluate 15 competency items that consist of eight global and five engineering competencies from the ABET Criterion 3 in addition to the GPA and work experience.

The comparison of the survey results between the Thai universities and the well-known Thai companies was conducted by rating 15 different competencies on a 5-point Likert scale based on the question: "How important is it for engineering students who will work globally to possess each of the listed global competency items?" The competencies, along with the average (mean) rating score and standard deviation, were rank-ordered from the most important to the least important based on the responses of the two groups of respondents who took the survey, as shown in Tables 4.8–4.9.

The results illustrate that each group considered both the standard engineering technical competencies from the ABET Criterion 3 and the global competencies essential for engineering students aiming to work globally.

Both groups rated the ability to work in an international team as an essential competency for engineering students. As many university programs tend to encourage students to work as a team through various programs [Rawboon et al, 2019b], which was also demonstrated in the previous research, the majority of the survey respondents from the industries that worked in the automotive and food and beverage industries, respectively, stated that the need for effective teamwork and leadership skills is critical [Rawboon et al, 2019a].

Table 4.8 Importance ranking of the competencies by the academia

Rank	Competencies	Academia (n=129)	
		Mean	SD
1	An ability to work in international teams	4.30	0.89
2	An ability to design and conduct experiments, as well as to analyze and interpret data	4.29	0.89
3	An ability to identify, formulate, and solve engineering problems	4.26	0.96
4	An ability to use the techniques, skills, and modern engineering tools necessary for engineering environment	4.23	0.84
5	An ability to communicate cross-culturally	4.22	0.96
6	An ability to exhibit a global mindset	4.21	0.86
7	An ability to apply knowledge of mathematics, science and engineering	4.20	0.83
8	An ability to appreciate and understand different cultures	4.13	0.90
9	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability	4.12	0.87
10	An ability to speak more than one language including English	4.02	1.05
	An ability to demonstrate world and local knowledge	4.02	0.82
11	An ability to live and work in a transnational engineering environment	3.92	0.85
12	An ability to understand international business, law, and technical elements	3.68	0.88
13	Pertinent applicable work experience	3.66	0.86
14	A high GPA	2.99	0.94

Table 4.9 Importance ranking of competencies by industry

Rank	Competencies	Industry (n=116)	
		Mean	SD
1	An ability to work in international teams	4.14	0.84
2	An ability to identify, formulate, and solve engineering problems	4.09	0.83
3	An ability to apply knowledge of mathematics, science and engineering	4.05	0.85
	An ability to use the techniques, skills, and modern engineering tools necessary for engineering environment	4.05	0.85
4	An ability to design and conduct experiments, as well as to analyze and interpret data	4.03	0.84
	An ability to exhibit a global mindset	4.03	0.85
5	An ability to speak more than one language including English	4.02	1.02
6	An ability to appreciate and understand different cultures	3.97	0.91
7	An ability to communicate cross-culturally	3.96	0.90
8	An ability to demonstrate world and local knowledge	3.93	0.81
9	An ability to live and work in a transnational engineering environment	3.91	0.85
10	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability	3.84	0.82
11	An ability to understand international business, law, and technical elements	3.67	0.82
	Pertinent applicable work experience	3.67	0.91
12	A high GPA	2.88	0.92

Further analysis, based on independent samples t-test, was performed to test if there are significant differences between academic perspectives and engineering industries' expectations on the importance of global competencies for engineering education. Statistical significance was set at standard 95 percent and the high-importance satisfaction items of the average value of each group are shaded.

Table 4.10 Comparison of ratings of the considered competence items

	Global Competency Item	Academia (n = 129)		Industry (n = 116)		T	P
		Mean	SD	Mean	SD		
1.	Ability to exhibit a global mindset	4.21	0.86	4.03	0.85	1.67	0.09
2.	Ability to appreciate and understand different cultures	4.13	0.90	3.97	0.91	1.43	0.15
3.	Ability to demonstrate world and local knowledge	4.02	0.82	3.93	0.81	0.88	0.38
4.	Ability to communicate cross-culturally	4.22	0.96	3.96	0.90	2.25	*0.03
5.	Ability to speak more than one language, including English	4.02	1.05	4.02	1.02	0.01	0.99
6.	Ability to understand international business, law, and technical elements	3.68	0.88	3.67	0.82	0.09	0.93
7.	Ability to live and work in a transnational engineering environment	3.92	0.85	3.91	0.85	0.16	0.87
8.	Ability to work in international teams	4.30	0.89	4.14	0.84	1.48	0.14
9.	Ability to apply knowledge of mathematics, science and engineering	4.20	0.83	4.05	0.85	1.39	0.17
10.	Ability to design and conduct experiments, as well as to analyze and interpret data	4.29	0.89	4.03	0.84	2.34	*0.02
11.	Ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, health and safety, manufacturability, and sustainability	4.12	0.87	3.84	0.82	2.66	*0.008
12.	Ability to identify, formulate, and solve engineering problems	4.26	0.96	4.09	0.83	1.53	0.13
13.	Ability to use the techniques, skills, and modern engineering tools necessary for engineering environment	4.23	0.84	4.05	0.85	1.67	0.10
14.	High GPA	2.99	0.94	2.88	0.92	0.95	0.34
15.	Pertinent applicable work experience	3.66	0.86	3.67	0.91	0.12	0.91

As demonstrated in Table 4.10, there are statistically significant differences between group for "Ability to communicate cross-culturally", "Ability to design and conduct experiments, as well as to analyze and interpret data", and "Ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, health and safety, manufacturability, and sustainability" at the 0.05 significance level.

The mean ratings on academic perspectives were examined in two dimensions: employment period and academic management position.

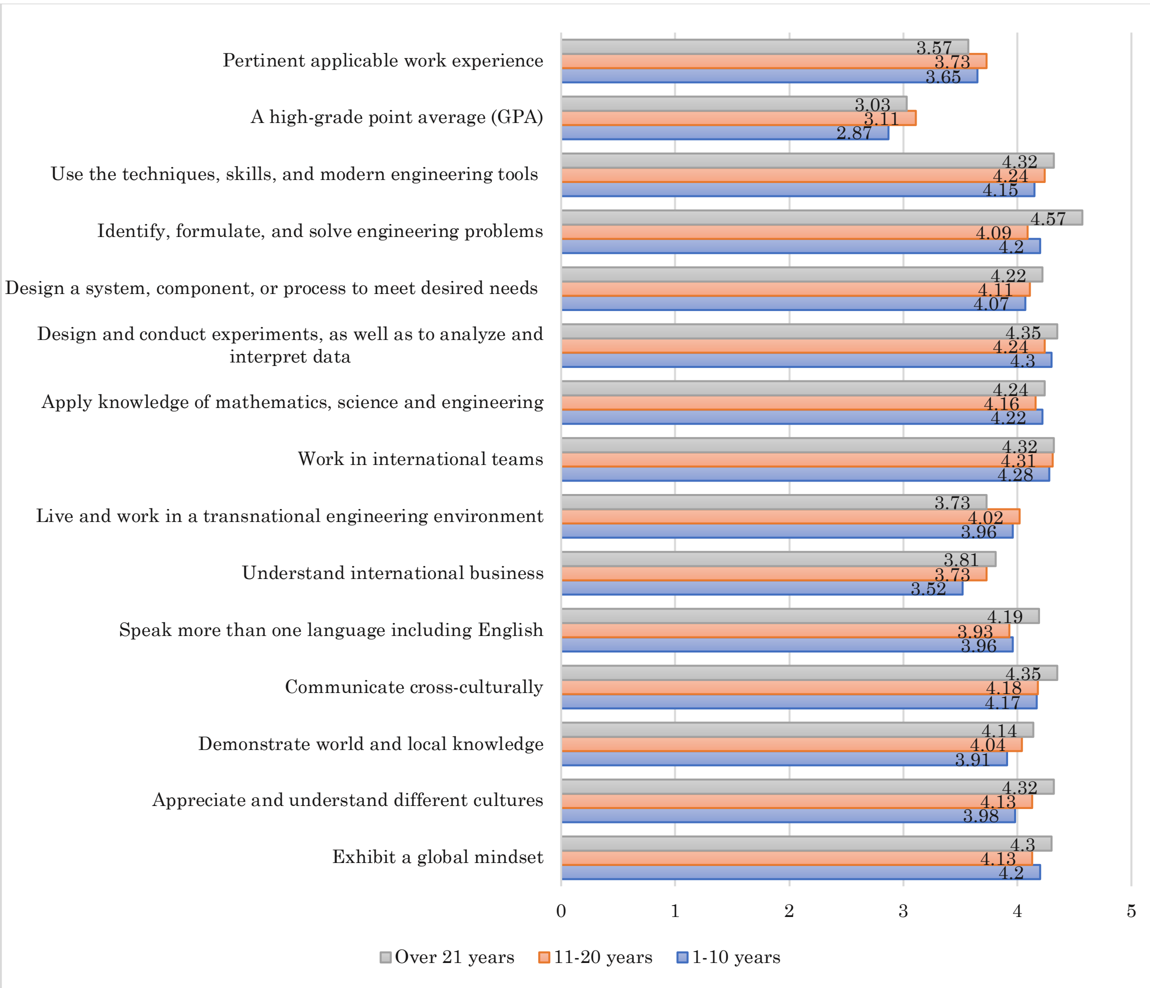

Figure 4.1 The mean ratings by employment period

According to the findings, academic personnel with more than 21 years of experience rated the ability to identify, formulate, and solve engineering problems as an essential competency for engineering students, followed by the ability to design and conduct experiments, analyze and interpret data, and ability to communicate cross-culturally. Academic employees with 1-10 years of experience regarded ability to design and conduct experiments, as well as analyze and interpret data, as the most important skill for engineering students, followed by ability to work in international teams.

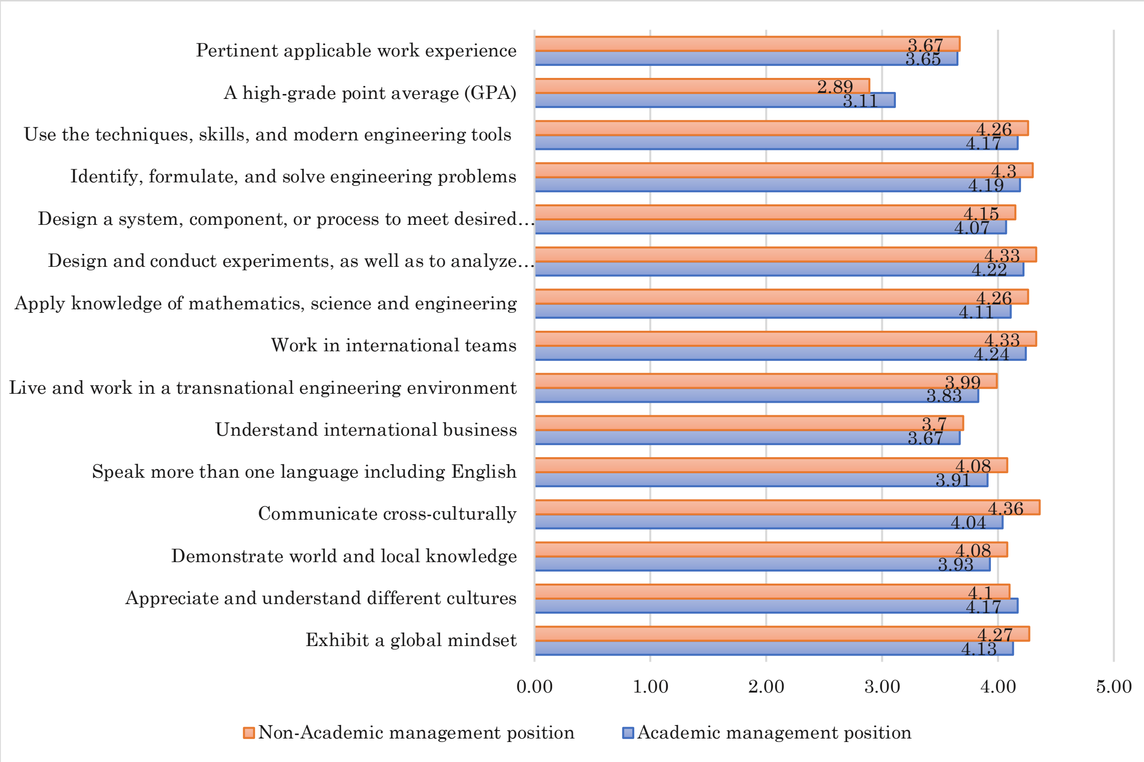

Figure 4.2 The mean ratings by academic management position

Academic persons in non-academic management positions regarded cross-cultural communication as a crucial skill for engineering students, whereas academic persons in academic management positions ranked ability to work in multinational teams as a vital talent for engineering students.

In particular, the following two out of eight global competencies are considered by Thai universities critical for engineering students: the ability to work in international teams and the ability to communicate cross-culturally. However, Thai industries considered two out of eight global competencies: the ability to work in international teams and the ability to exhibit a global mindset (Fig. 4.1). It was evident that the respondents tended to value global competencies because Thailand is committed to building the ASEAN community and expand cross-border alliances between academics, businesses, and industries. Also, to be mutually recognized, Thai universities tend to standardize education and prepare their students to be successful in global and diverse environments.

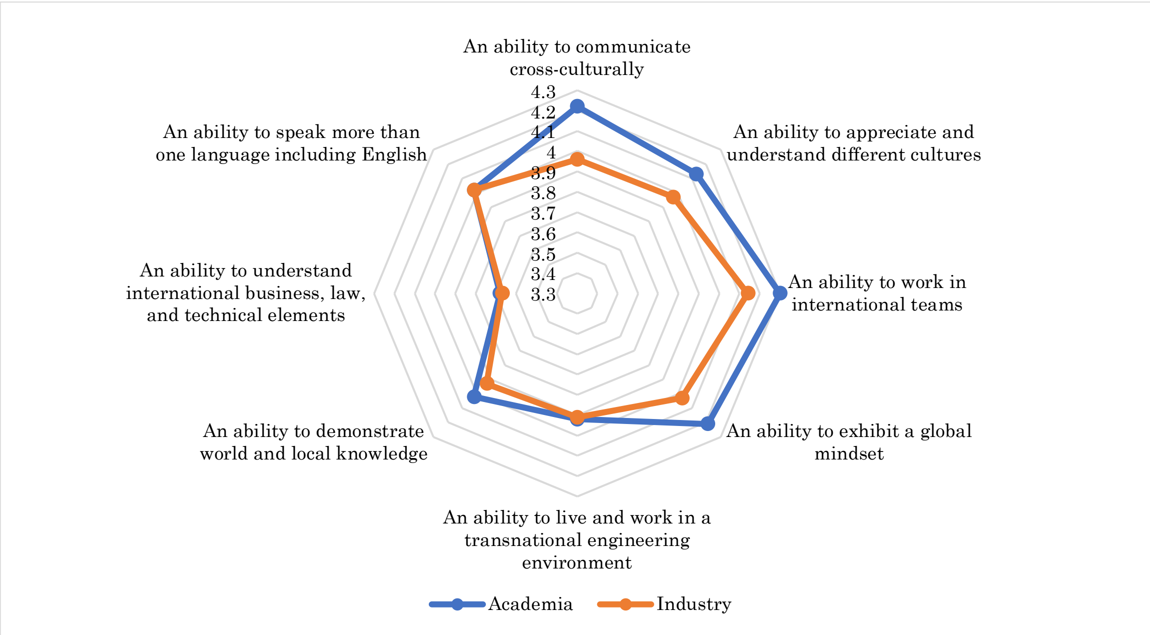

Figure 4.3 GAP values between the academia and industry perspectives on the importance of global competencies for engineering education

This study also shows that both groups considered the following technical engineering knowledge and competencies as the most crucial core competencies, as they are useful and commonly applied in practical industrial environments (Fig. 4.2).

1. The ability to design and conduct experiments as well as to analyze and interpret data;
2. The ability to identify, formulate, and solve engineering problems;
3. The ability to use the techniques, skills, and modern engineering tools necessary for engineering environment.

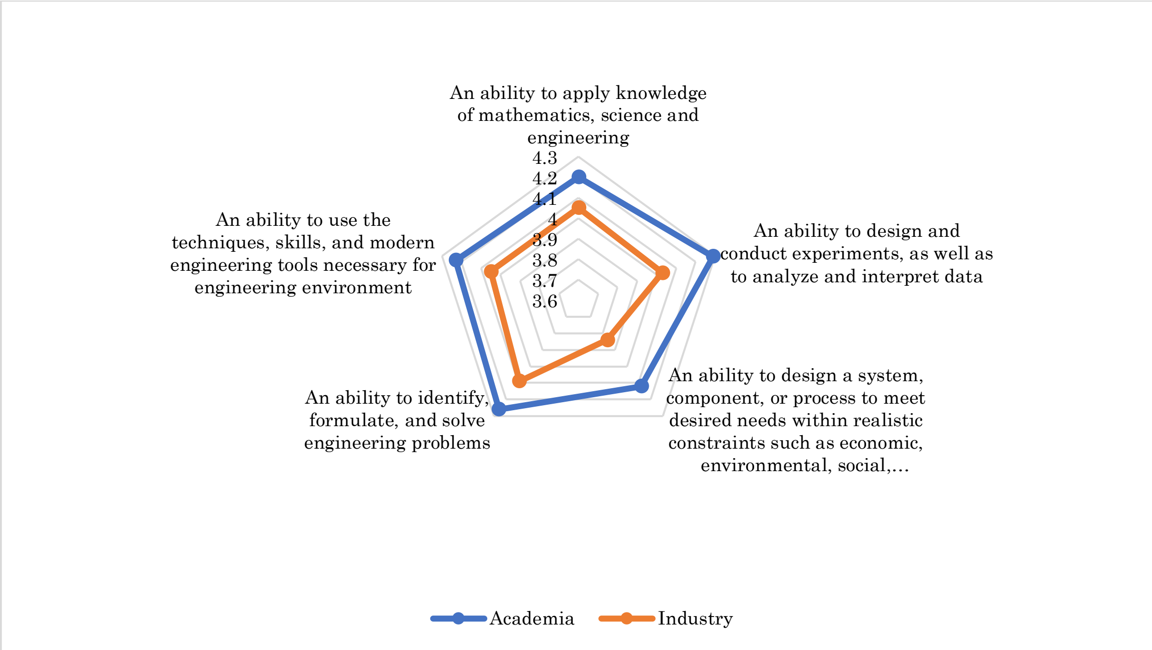

Figure 4.4 GAP values between the academia and industry perspectives on the importance of technical competencies for engineering education

The GPA and work experience were also deemed vital for engineering students, and the graduation requirements were shown in Warnick and Oda's survey [Warnick, 2010; Oda et al., 2018]. Nonetheless, according to both groups, the GPA and work experience were not considered as significant criteria for engineering students to obtain their university degrees, especially for those who seek to work in Thailand, as engineering graduates can learn more efficiently about their roles and acquire the necessary experience in the workplace (Fig. 4.3).

The survey results also indicated that 71% of the engineering education stakeholders and leaders (deans, faculties, educators, lecturers, and others) from Thai universities used to work and exhibited collaboration with the industry sector in Thailand. Therefore, the perspective of the vital satisfaction competency items of Thai universities did not differ much from that of the industries' expectations.

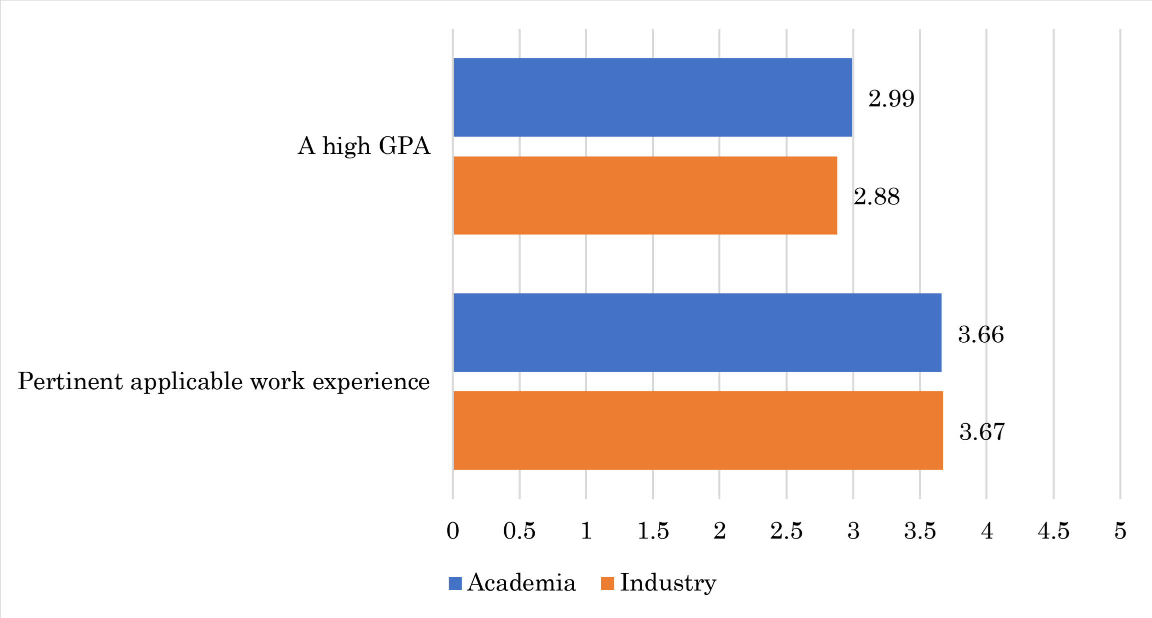

Figure 4.5 GAP values between the academia and industry perspectives on the importance of GPA and work experience

4.5 Conclusion

Due to globalization, the required education and skills to enhance success in global workplaces are rapidly changing. The main objective in higher education has been developing professionals who can display competences in their specific work fields. Hence, the development of such competences and skills has been widely discussed, highlighting that the understanding of the industries' perspectives might be the best approach to fulfill this requirement. However, various research also revealed inconsistencies between the competencies developed in engineering as a part of educational programs and the required competencies of engineers in the actual world.

The study was to identify the gaps between academia and engineering industries by investigating the perceptions of higher education institutions when it comes to the importance of global competencies for engineering graduates who aim to work globally and then comparing them with the perspectives of multinational Thai companies in Thailand. The following research questions were utilized to address this purpose:

Research Questions 1b: Is there a gap between academic perspectives and engineering industries' expectations on the importance of global competencies for engineering education?

The reported research findings here provide some insights into the perspectives of the educational stakeholders and leaders (deans, faculties, educators, lecturers, and others) of the engineering departments in Thai universities regarding the importance of global competencies for engineering graduates aiming to work globally. Also, as part of the new engineering graduates' building programs, these perspectives were compared with those of the well-known and multinational Thai companies that are based in Thailand.

The results summarized that both the standard engineering technical competencies of the ABET Criterion 3 and the global competencies are considered essential for engineering students. In particular, the ability to work in international teams, the ability to communicate cross-culturally, the ability to exhibit a global mindset, and the ability to speak more than one language including English are important competencies for engineers to develop.

Higher education engineering institutions throughout the world are encouraged to identify opportunities within each course they teach to facilitate the interaction of engineers within a global environment. Efforts to develop global competence among engineering students may include team-based projects, work-focused projects in different countries, the interaction of engineers in a multicultural environment, international educational partnerships among colleges and universities throughout the world, and the use of technology to develop cross-cultural competence through virtual teams. Students' involvement in a global environment throughout their education versus a single study abroad experience will greatly enhance the capabilities of engineering graduates to succeed in a global environment. Based on this study, particular focus should be placed on incorporating each of the required global competencies into the curriculum.

As the respondents in many Thai universities have been efficiently collaborating with the industry sector, therefore, the perspectives of the educational university sector concerning the vital satisfaction competency items tend to be almost the same as the industry sector. Thus, these results will exhibit a positive impact on the development of future professional engineers in the educational sector in

Thailand. Overall, stakeholders and leaders should determine the necessary global visions in the engineering education field to set up directions for new pedagogy approaches and curriculum reforms. As a result, engineering students can compete and excel in global environments and also meet the international market and globalization demands that link the whole world socially and economically.

Chapter 5

Future Competencies for The Demanding Careers of Industry 4.0

5.1 Background and purpose of the study

The fourth industrial revolution, also known as Industry 4.0, is the convergence of several emerging concepts and new technologies, such as the Internet of things, artificial intelligence (AI), cloud computing, autonomous vehicles, robots, and machine learning (Deloitte Development LLC, 2020). In the context of Industry 4.0, these new technological systems will be linked with organizational processes to transform industries, enabling real-time connections between humans, machines, and smart objects (Kohnová et al., 2019).

The transformations that have occurred since the first industrial revolution substantially impacted human employment. Currently, a significant gap exists between present human resource capabilities and prospective industrial needs. Hence, new roles must be devised, and new skills must be inculcated to align with the emergent technological advancements (Drath & Horch, 2014). The fast-changing work environment influenced by Industry 4.0 will generate new categories of jobs and occupations. Some research has indicated that low-skilled jobs will be eliminated; however, the demand for higher-skilled workers will grow. Thus, the job losses for low-skilled workers will be offset to a great extent by creating new, highly skilled job opportunities (BRICS Business Council, 2017). The current workforce must now acquire discrete and more technically advanced knowledge and skillsets. In particular, university graduates forming the future workforce must imbibe multidisciplinary skills to satisfy industry demands (Cicek et al., 2019).

The university discharges a vital role in the development of the knowledge, skills, attitudes, and values that can empower people to contribute to an inclusive and sustainable future and benefit from it. For those working in a rapidly changing world, learning how to devise clear and purposeful goals, coordinate and work with people with different perspectives, discover challenging opportunities, and identify multiple solutions for the resolution of complex problems will be essential. Universities and other higher education institutions must prepare students to not only focus on knowledge and technical abilities but also hone their nontechnical abilities and thus meet the demands of changing workplaces and societies.

The Asia Pacific region is currently transmogrifying from the global manufacturing hub to the innovation center for the new knowledge economy. Simultaneously, this region remains a major foreign direct investment target. Many European and US companies are relocating their assembly lines and manufacturing plants to this region to leverage the lower cost base, the abundant availability of workers, and proximity to a growing marketplace. Nevertheless, low-cost labor will not be enough to ensure the region's competitiveness in the decade ahead. Infrastructure, workforce skills, and productivity will be critical determinants of the region's projected growth. All industry value chains now increasingly rely on R&D and innovation. Combined with the evolution of manufacturing and emerging technologies, these shifts signify that countries across Asia must amend investment priorities and develop new types of skillsets to compete in a more knowledge-intensive trade landscape.

The Asian region has become a pivotal driver of global economic growth. Thus, new demands vis-à-vis qualifications, broader knowledge, and skillsets must urgently be addressed to meet the new industrial revolution and face these emerging challenges. The roles discharged by education and universities must be discussed from the perspective of research into new job opportunities and skill requirements. Southeast Asian countries can be pivotal to the growth of some future industries (ITRI, 2019). Scholars must conduct surveys of competencies that global industries are likely to require as they promote their businesses in Southeast Asian nations. This task is crucial not only for Asian universities but also for higher educational institutions in other regions because a large percentage of university graduates will probably shortly work in the Asian region. Thus, universities across the globe should reform their educational strategies and consider the competencies that will be required in the future by industries associated with this part of the world.

Studies on the key competencies required for crucial professions for Industry 4.0 are currently scant. Therefore, this investigation aimed to review the extant literature on capabilities required by employers from graduates to handle future technology and market demands as future workers. In so doing, this review identified the future competencies for three demanding careers representative of the high-skilled requirements of Industry 4.0: robotics engineers, data scientists, and food designers. Quantitative data were collected, and the results of the conducted analyses reflected real industry-based needs. This paper will benefit universities by making them aware of market-related circumstances and facilitating their endeavors to modify curricula. Further, students can use the current study's findings to prepare themselves for the novel challenges and opportunities that will evolve over the next decade.

5.2 Research Question

Research Question 1c: What are the future competencies for three high-skilled jobs in Industry 4.0: robotics engineers, data scientists, and food designers?

Specifically, the objectives of this study are to identify the competencies of three positions that are expected to be in high demand in Industry 4.0: robotics engineers, data scientists, and food designers.

5.3 Defining Industry 4.0

The term Industry 4.0 was coined in 2011 at the Hanover Fair. Subsequently, the German government adopted the term in 2013 as a strategic initiative to revolutionize the manufacturing industry (Li, 2017; Xu, 2018). The suffix 4.0 indicates that this development continues the three previous industrial revolutions and designates the current technological thrust as the fourth transformation in industrial production. Lately, Industry 4.0 has attracted increasing interest because of the discrete advantages it offers to the manufacturing organizations. As a concept, Industry 4.0 describes a new phase of manufacturing operations that combines a set of emergent and convergent technologies to add value to the entire product lifecycle (Dalenogare et al., 2018). These novel technologies aim to offer ameliorated conditions to workers to enhance productivity (Kagermann et al., 2013). Thus, humans and machines are considered an integrated socio-technical mechanism in the conception of Industry 4.0 (Thoben et al., 2017).

The European Union governments have prioritized Industry 4.0 and have adopted large-scale Industry 4.0 policies to ensure inclusive growth that can create productive employment and decent jobs (European Commission, 2017). As the newly industrialized nation of Southeast Asia, Thailand must prepare for the next stage of growth; it is currently implementing the Industry 4.0 concept. Recently, Thailand has attuned its economic model to the world economy by announcing a new national innovation-driven economic development policy called Thailand 4.0 (The National Reform Council, 2016). As a concept, Thailand 4.0 is closely related to Industry 4.0 idea and is expected to lead Thailand out of the middle-income trap. It is designed to make Thailand a stable, wealthy, and sustainable economy in the dynamic global context.

However, the biggest challenges for newly industrialized countries, such as Thailand, India, Pakistan, Indonesia, Brazil, Malaysia, and Nigeria, particularly concern the shortage of qualified technical and skilled workers (Bahrin et al., 2016; Jones & Pimdee, 2017; Berawi, 2018).

Consequently, students' readiness for the Industry 4.0 must be investigated, especially at universities and higher education institutions that will shortly produce the workforces of such nations. Essential modifications are thus anticipated to occur because of the Industry 4.0 revolution.

5.4 Industry 4.0: The emerging challenges and career opportunities

Change is faster and more unpredictable in the current global scenario. Enterprises and organizations must react very quickly to the challenges and opportunities presented by the business world (Saniuk et al., 2014). The implementation of emerging technologies is expected to bring certain transformations in social, economic, environmental, technical, legal, and political systems (Hecklau et al., 2016; Hinton, 2018). Undoubtedly, lower-skilled workers confront a high risk of becoming unemployed or underemployed. Low-skilled and routine jobs are shortly likely to be replaced by automation and robots. In 2015, McKinsey predicted that automation could displace 45% of the jobs currently performed by human labor and that technology would probably substitute 5% of the full-time jobs in the developing world. In 2016, the World Bank projected that 66.6% of the existing manual jobs could also be replaced by automation and robotics. However, the increased productivity attained using Industry 4.0 technologies could exert other effects on an industry's value chain that would generate novel job prospects in targeted industries such as architecture, engineering, computers, and mathematics (Balliester & Elsheikhi, 2018). The World Economic Forum has tracked the labor market impact of Industry 4.0 and has reported new roles that are likely to open at the forefront of the data and AI economy. It has also divulged new functions that could evolve in the engineering, cloud computing, and product development domains. This set of emerging professions reflects the continuing importance of human interaction in the new economy (WEF, 2020).

The ongoing COVID-19 pandemic has certainly fast-tracked digital transformation across all sectors. Digitalization has been crucial to the achievement of organizational transformations, and the current pandemic has accelerated industry-based demands for a more skilled workforce. The challenges concern how employers can match employees to new roles and responsibilities and ensure that their employees acquire the new skillsets demanded by a digitally transforming world.

The demand for highly skilled human resources in target industries is increasing as Thailand moves toward an innovation-driven economy. The knowledge and skill-based requirements for future industries are also becoming more complex. To respond to this new demand during its digital transformation and in the post-COVID era, the Thai workforce development agencies nominated the Office of National Higher Education Science Research and Innovation Policy Council (NXPO) to survey the demand for high-skilled human resources and key functional competencies for 12 targeted S-curve industries. These industries include next-generation automotive manufacture, smart electronics, affluent medical and wellness tourism, agriculture and biotechnology, food for the future, automation and robotics, logistics and aviation, biofuels and biochemicals, the digital sector, medical services, defense, and education development (NXPO, 2020). These industries are expected to represent the business strengths of Thailand and will become the foundation that tethers both education and business in congruence with the Thailand 4.0 policy. In this manner, Thailand hopes to achieve economic prosperity, social well-being, increased human value, and environmental protection.

Interestingly, the NXPO's survey report revealed an existing demand for nearly 180,000 new graduates to serve in highly demanded positions in the country's 12 key industries: engineers, data scientists, technicians, developers, and marketing personnel. The survey also highlighted that the digital industry would tender the highest demand for personnel over the next five years. This sector will expectedly need a total of 30,742 workers, particularly 5,767 data scientists. Moreover, the robotics industry is projected to require 10,020 critical positions to be filled even though the country's robot production is still minimal and most of the robots used in Thailand are imported from countries such as Japan and Germany. However, the country's demand for robots continues to increase. Thus, the robotic industry is estimated to demand 2,697 data scientists, 1,869 robotic control engineers, and 1,862 mechanical engineers. Meanwhile, the developing food industry sector will probably require 12,458 employees between 2020 and 2024 (NXPO, 2020).

Thailand's current predominant challenges are vested in the fact that its small- and medium-sized enterprises (SMEs) lack the technological know-how and the requisite science, technology, and innovation capabilities. Their skill base must shift to more sophisticated, higher value-added activities. In addition, Thailand must foster innovation in research and development (R&D) and undertake economic activities to upgrade its technological levels, enhance organization, encourage innovation, and introduce new products and services.

Therefore, Thailand should focus on developing a highly skilled workforce capable of satisfying the job-skill requirements of Industry 4.0 technologies. The country should also prepare its graduating youth and future workers to cope with new challenges posed by Industry 4.0. Only then can Thailand successfully manage sustainable organizational performance and accomplish its transition to Industry 4.0.

However, studies on the key competencies required by Industry 4.0 players for the crucial professions are only a few. Hence, this study intended to identify the competencies projected for the most demanded careers of the Thai version of Industry

4.0: robotics engineers, data scientists, and food designers. These careers are thought to be representative of the highly skilled workers required for the industries with the most potential according to NXPO's report on the projected demands for high-skilled human resources: automation and robotics, the digital sector, and food for the future.

5.5 The identification of key competencies for the future

The currently evolving Industry 4.0 has entirely transformed how industries or businesses function and develop. Thus, industry players must constantly confront new challenges. Jobs created by Industry 4.0 will require higher-level skills that will mandate novel qualifications and skillsets. In this sense, the importance of soft skills, such as communication, self-organization, management, and teamwork skills is likely to increase (Kergroach, 2017).

Such changes will dramatically affect the job market, more specifically in terms of the aptitudes in demand and recruitment criteria. The World Economic Forum (2020) recommends several major changes in how businesses regard and manage their employees, both immediately and in the longer term. Further, this report projects a significant shift in the required skills in 2025 and lists the demanded top five skills will encompass analytical thinking and innovation, active learning and learning strategies, complex problem-solving, critical thinking and analysis, and creative originality and initiative.

Most studies involving human competencies attend to the effects of technologies, for example, the ability to engage in e-commerce, or digital competence. Ferrari (2013) defined digital competence as a set of knowledge, skills, and attitudes required for the use of information and communication technology (ICT) and digital media to perform tasks (e.g., problem-solving, communication, managing information, collaboration, the creation and sharing of content, and the effective, efficient, appropriate, critical, creative, autonomous, flexible, ethical, and reflective construction of knowledge for work, leisure, participation, learning, socializing, consuming, and empowerment.

NXPO has outlined the required functional competencies for critical positions in 12 targeted S-curve industries in Thailand. The following set of functional competencies are needed for robotics engineers: robot programming and programming pendant; robot troubleshooting; embedded systems; servo motor controller; digital signal processing; hydraulics and pneumatics; robotics maintenance and installation; sensor technology; and error compensation (NXPO, 2020).

NXPO already provides the important knowledge and required technical competencies for future careers of Industry 4.0. From them, researchers have increasingly discovered that social, personal, and methodological competencies are more frequently mentioned than technical abilities. Thus, we can assert that technical capabilities are necessary but not as critical as other nontechnical aptitudes (Rahmat et al., 2020). Therefore, this study focused on the exploration of three crucial categories of professional competencies. The literature review revealed that most capabilities are the criteria expected to be required by industry players. Table 5.1 summarizes these aptitudes.

First, social competencies include social values, and motivations and encompass skills such as intercultural interaction, communication, networking, teamwork, the ability to transfer knowledge, and leadership. Social competency is defined as the ability to communicate and cooperate with others (Hecklau et al., 2016) and effectively handle social interactions.

Second, personal competencies comprise personal traits and abilities and may be exemplified by attributes such as flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset, and compliance (Hecklau, 2016). Personal capabilities are related to individual characteristics that fit into organizations that direct behavioral choices and decision-making [Barrick, 2000].

Third, methodological competencies denote generic skills and abilities necessary primarily for general problem-solving and decision-making (Hecklau et al., 2016) and incorporate qualities such as creativity, entrepreneurial thinking, problem-solving, conflict solving, decision-making, analytical skills, research skills, and efficiency orientation.

Table 5.1 The competencies essential for industry 4.0

Categories	Key Competencies	Reference
Social Competencies	Intercultural skills, language skills, communication and networking skills, leadership skills, ability to compromise and cooperate, ability to work in teams, ability to transfer knowledge, and acceptance of change	Hecklau et al., 2016; Sallatia et al., 2019; Suleman & Laranjeiro, 2018; Katarzyna & Anna, 2017; Fitsilis et al., 2018; Popkova & Zmiyak, 2019; Hollister et al., 2017; Ahmed et al., 2012; Rahmat et al., 2019; Supjarerndee et al., 2002; Asonitou, 2015.
Personal Competencies	Flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset and compliance, communication skills, adaptability, emotional intelligence, and willingness to learn	Hecklau et al., 2016; Sallatia et al., 2019; Katarzyna & Anna, 2017; Fitsilis et al., 2018; Motyl et al., 2017; Hollister et al., 2017; Ahmed et al., 2012; Miao et al., 2017; Rahmat et al., 2019; Supjarerndee et al., 2002; Jameson et al., 2016; Asonitou, 2015; Cortellazzo et al., 2020.
Methodological Competencies	Creativity, entrepreneurial thinking, problem-solving, conflict solving, decision-making, analytical skills, research skills, efficiency orientation, and critical thinking.	Hecklau et al., 2016; Katarzyna & Anna, 2017; Fitsilis et al., 2018; Aluko, 2014; Akman & Turhan, 2018; Abbasi et al., 2018; Fareri et al., 2020; Pinzone et al., 2017; Popkova & Zmiyak, 2019; Finch et al., 2013; Motyl et al., 2017; Hollister et al., 2017; Ahmed et al., 2012; Rahmat et al., 2019; Supjarerndee et al., 2002; Jameson et al., 2016; Kinnunen & Parviainen, 2016; Asonitou, 2015.

5.6 Methodology

The methodology proposed for the present study comprised five stages for the identification of future competencies in implementing Industry 4.0. The needed competencies for the three careers in demand were identified at the first stage based on the literature review. The second stage involved the intensive investigation of the required competencies through individual interviews with senior specialists to expand the scope of the literature review. In the third stage, the literature review and expert inputs were evaluated, and the listed competencies were analyzed through focus group discussions with highly qualified managers and key players at the forefront of Thai and multinational companies in Thailand. The focus group members included lecturers with previous experience in companies or with numerous years of teaching experience at university in related domains. After a consensus was achieved, a questionnaire survey and in-depth interviews were conducted with selected experts in the automotive, digital, and food industry domains and the lecturers in related disciplines to confirm the essential future competencies for the three future careers. A final analysis was then accomplished to verify the robustness of the accomplished evaluation. Figure 5.1 presents the proposed framework for identifying the future competencies for the stated careers toward the implementation of Industry 4.0.

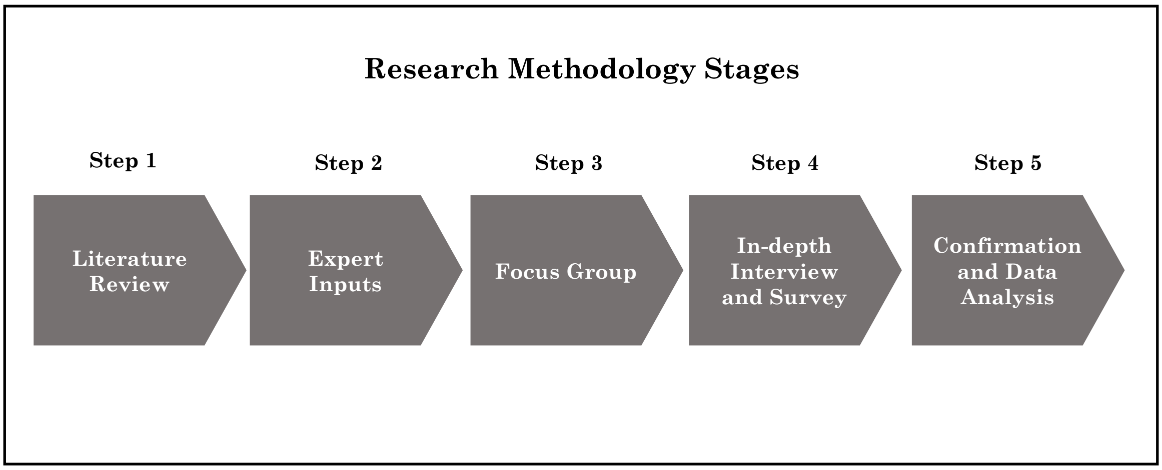

Figure 5.1 Research methodology stages

The literature review of relevant texts and previously conducted research at the first stage allowed us to attain information pertinent to the study using the keyword "competency" for the three future careers. This also allowed us to explore the needed skills and aptitudes.

The literature review was extended at the second stage via an intensive investigation of the required competencies through individual interviews with three senior experts in related fields. The criteria for selecting experts were defined to obtain appropriate data as highly qualified specialists who had accrued previous experience in companies or had accumulated numerous years of university-level teaching or education-related experience in the pertinent areas of engineering, information systems, information technology, and food. The required competencies for future careers in Industry 4.0 businesses were listed and sorted by category.

To evaluate the literature review and expert inputs, we analyzed the listed competencies at the third stage via focus group interviews with highly qualified participants in relevant domains. The focus group interviews were conducted as recommended by Krueger and Casey (2000) and three focus group discussions were held with an aggregate of 33 participants. The focus group participants were currently employed and highly qualified managers and key players at the forefront of Thai and multinational companies in Thailand. They also included lecturers with previous experience in companies or numerous years of university-level teaching or education-related experience in the areas of engineering, information systems, information technology, and food. Lecturers command a general understanding of competencies and apply competency-targeted teaching; hence, we targeted this group. Most educators are also involved in research and are therefore aware of Industry 4.0, its relevance, and the importance of building competencies for future employees.

The participants were also accorded time to deliberate and think about Industry 4.0 related topics during the focus group discussion and were thus positioned in the appropriate mindset for the contemplation and construction of ideas. The given group dynamics and workshop settings encouraged the inclusion of lecturers and professors. Most of the educators who participated could offer practical insights from their previous jobs and represented recognized representative bodies and official voices of Thai tertiary education tasked with producing the most employable graduates.

The researcher moderated all focus groups, and identical semi-structured guidelines were applied for all the focus groups to ensure that the findings were comparable. The design thinking process was applied to the focus group guidelines to derive the competencies apt for Industry 4.0. The participants were presented with typical work scenarios and the challenges of Industry 4.0. Questions were subsequently asked about the competencies that robotics engineers, data scientists, and food designers should bring to their jobs in such a scenario.

The supporting team recorded the focus groups. The competencies gleaned from the literature review, and the first group interview was collated as the set of initial data. If a subsequent focus group mentioned a new competency that was not part of the initial data, it was recorded in the list as a new competency. The lists were finally compared, and the differences were discussed until a common decision could be achieved on the critical competencies. The required competencies for each group were analyzed, categorized, and collected at the end of this stage for the design of the questionnaire survey administered at the next stage.

To evaluate the set of essential competencies determined at the third stage for the three future careers, we conducted a questionnaire survey and in-depth interview at the fourth stage with selected experts and lecturers from the automotive, digital, and food industries and related disciplines. Respondents were asked to indicate the importance of the selected competencies on a 5-point Likert-lime scale to augment validity and reliability (Spooren et al., 2007). The final collated list included 20 required proficiencies for robotics engineers, 22 aptitudes for data scientists, and 14 required abilities for food designers. Six experts from each group completed the survey. Subsequently, all data obtained from the respondents were analyzed to determine the convergence of participant opinions and to provide controlled feedback. The fifth stage aimed to invite the respondents to discuss their scoring in light of the group response and decide whether they would like to modify their original choices. The individual respondent scores and central tendencies (mean, median, and mode) were provided to the respondents so they could assess the diversity of responses. This step also allowed the experts to confirm that the researchers had accurately recorded their responses.

5.7 Analysis and results

This paper aimed to identify the future competencies for three careers that are representative of the demand for highly-skilled personnel needed in potential industries during Industry 4.0: robotics engineers, data scientists, and food designers. The following research questions were utilized to address this purpose:

Research Questions 1c: What are the future competencies for three high-skilled jobs in Industry 4.0: robotics engineers, data scientists, and food designers?

Three careers projected to be in demand in Industry 4.0 were selected for the study: robotics engineers, data scientists, and food designers. The results obtained from the first to the final stage were analyzed and are reported in three distinct sections to display most of the competencies that should be inculcated into the three groups of future graduates who wish to undertake the stated careers. The competencies, along with the average (mean) rating scores and standard deviations (SD), were ordered ranking from the most important to the least important ability derived from the assessment of the survey responses.

5.7.1 Competencies for Robotics Engineers

Robots have become an essential part of our world in recent years. Hence, there now exists a significant demand for robotics engineers who can design and develop solutions for every anticipated problem. Robotics engineering is a multidisciplinary field. Robotics engineers are responsible for the design, testing, and construction of robots that are productive and safe to operate as well as economical to purchase and maintain. Robotics engineers also create an integrated environment between people and machinery.

Moreover, non-technical competencies are crucial for robotics engineers, who must work with team members across multiple departments. Table 5.2 displays 20 competencies listed by experts in the automation and robotics sector and by lecturers in related disciplines. The most important competencies were patience and persistence, active learning with a growth mindset, analytical thinking and innovation, creative integration, design thinking, and systems thinking. The competency of patience and persistence was identified as a specific requirement of paramount importance because robotics engineers must proficiently handle work tools and analytical instruments. They must master the qualities of patience and persistence to resolve difficult problems and to provide creative solutions to technical challenges. Such processes require much hypothesizing and experimentation before the best results are discovered. Hence, robotics engineers must be able to work long hours, weeks, months, and even years before a finished project is actualized.

Table 5.2 The assessment of competencies for robotics engineers

Competencies	Mean	SD	Ranking
Patience and persistence	5.00	0.00	1
Active learning with a growth mindset	4.83	0.41	2
Analytical thinking and innovation	4.83	0.41	
Creative integration	4.83	0.41	
Design thinking	4.67	0.52	3
Systems thinking	4.67	0.82	
Creativity, originality, and initiative	4.50	0.55	4
Effective negotiation and persuasion skills	4.50	0.84	
Observation skills and curiosity	4.50	0.84	
Adaptability to change	4.50	1.22	
Complex problem-solving	4.33	0.82	5
Critical thinking	4.33	0.82	
Team-building	4.33	1.21	
Emotional intelligence	4.33	1.21	
Leadership and social influence	4.33	1.21	
Project and engineering management	4.17	1.17	6
Time management	4.17	1.33	
Effective communication	4.00	1.10	7
Coordinating with others	4.00	1.10	
Customer orientation	3.33	1.37	8

5.7.2 Competencies for Data Scientists

Data scientists must collaborate closely across different job roles because of the interdisciplinary and complex nature of data science and machine learning tasks. They need diverse expertise in many complex data science projects. A data scientist is a professional responsible for the collection, analysis, and interpretation of extremely large amounts of data. In businesses, data scientists typically work in teams to mine big data for information that can be used to identify new products and services to fit the behaviors and needs of their customers. The industry demand for data scientists has grown significantly over the years. As has been noted above, the NXPO report highlighted that the digital industry would display the greatest workforce demand and 5,767 data scientists are expected to be inducted over the next five years.

Table 5.3 evinces a total of 22 competencies derived for data scientists during this study. Data visualization and presentation, associative skills, applicative thinking, and great data intuition represented the most desired proficiencies. Data visualization and presentation denoted the competency most frequently mentioned for data scientists and all the respondents from this sector considered this ability to be crucial for data scientists in the Industry 4.0 era. In business terms, data scientists must be proficient at the evaluation of data and must be able to explain their findings clearly and fluently to both technical and non-technical audiences. This critical element helps to promote data literacy across the organization and amplifies the ability of data scientists to make an impact.

Table 5.3 The assessment of competencies for data scientists

Competencies	Mean	SD	Ranking
Data visualization and Presentation	5.00	0.00	1
Associative skills	4.83	0.41	2
Applicative thinking	4.83	0.41	
Great data intuition	4.83	0.41	

Effective communication	4.67	0.52	3
Ability to present ideas in a clear and concise manner	4.67	0.52	
System analysis and evaluation	4.67	0.52	
Research skills	4.67	0.52	
Curiosity	4.67	0.52	
High integrity and ethics	4.67	0.52	
Complex problem-solving	4.50	0.55	4
Active learning and development	4.50	0.55	
Adaptability to change	4.50	0.55	
Creative thinking	4.33	0.52	5
Teamwork	4.33	0.82	
Project management	4.33	0.82	
Emotional intelligence	4.33	0.82	
Critical thinking	4.33	1.63	
Coordinating with others	4.17	0.75	6
Business acumen	4.17	0.75	
Storytelling	4.00	0.63	7
Customer orientation	3.83	0.41	8

5.7.3 Competencies for Food Designers

Food design is a recent discipline that includes the process of design studies and research that generates new food-related products. This discipline forms part of industrial design and is charged with the creation and design of food or of parts of complex food products. Food designers require the expertise of managing and leading invention projects from ideation through the scaling-up of new products and services, the improvement of product quality, value transformation savings, and production capacities for global operations. The role requires them to discover, develop, and apply new ingredient technologies enabling the development of innovative new foods and the creation of compelling culinary experiences for a wide variety of consumers toward the creation and promotion of a more delicious, healthy, and sustainable future.

Table 5.4 exhibits the survey results obtained from the responses of experts in the "food for the future" sector and from the lecturers in relevant disciplines regarding the essential competencies for food designers. An aggregate of 14 competencies was ultimately listed, of which the topmost included the knowledge of the trends of food analytics, food innovation thinking, food designing expertise, continuous learning, effective communication, and understanding the contexts of food. Three of the competencies, the trends of food analytics, food innovation thinking, food designing expertise were recognized by experts to be key determinants of the development potential of food designers. Such thinking probably emanated from the view that the mentioned three competencies were deemed critical for increased efficiency and for the acquisition of strategic advantages. An innovative mindset and the knowledge of trends of food analytics are critical for the discovery, advancement, and evaluation of new technologies in food or for the processing of R&D initiatives toward the provision of innovative, timely, and cost-effective improvements to new or existing products or processes. Moreover, food designers also require leadership competencies and internal and external expertise in specific disciplines. Further, they must remain updated with the latest developments and technologies.

Table 5.4 The assessment of competencies for food designers

Competencies	Mean	SD	Ranking
Knowing the trends of food analytics	4.80	0.45	1
Food innovation thinking	4.80	0.45	
Food designing expertise	4.80	0.45	
Continuous learning	4.40	0.89	2

Effective communication	4.20	0.84	3
Understanding the contexts of food	4.20	0.84	
Entrepreneurship	4.00	1.22	4
Consulting	4.00	1.22	
Leadership	3.80	0.45	5
Service mindset	3.80	1.64	
Storytelling	3.80	1.64	
Partnering	3.60	1.14	6
Negotiation skills	3.20	1.30	7
Adaptability	3.00	1.58	8

Another widely known method of defining competency is to classify it into personal, social, and methodological elements. Personal competencies comprise personal traits and abilities and include motivations, attitudes, as well as social values. Social competencies encompass attitudes, abilities, and skills that allow people to easily form social relationships and cooperate and communicate with others. These competencies enable people to reasonably achieve common goals in social interactions. Finally, methodological competencies include the abilities and skills for general problem-solving and decision-making. They enable workers to independently and purposefully resolve new and complex problems using learned thinking and working methods.

The World Economic Forum has also highlighted that the demand for technology-related and non-cognitive soft skills is rising faster than ever before because of rapid advances in technologies and shifts in job roles and occupational structures [WEF, 2018]. These changes will gradually enhance new types of education and training to assist young people to attain the critical requisite skills for personnel at risk of their jobs becoming obsolete. Such expectations necessitate the development of appropriate employment and skill expansion policies.

The literature review yielded three categories of crucial competencies as an increasing number of researchers were found to emphasize social, personal, and methodological competencies in higher frequency than technical competencies. Despite the diverse aspects described by the listed capabilities, the three groups displayed some identical competencies as summarized in Table 5.5

The results revealed that most of these competencies should be inculcated in all three groups of graduates aiming to fill the emergent demand for the stated careers. These competencies are marked in blue and include effective communication, active learning, adaptability to change, and leadership. Interestingly, these competencies are expected to form the core abilities for all future personnel.

Hence, employees of the future should imbibe these competencies at advanced levels to work successfully in the Industry 4.0 era, which is primarily centered on tasks that are multidisciplinary. Communication skills are critical because of the increase of virtual work with globalized teams and facilitate individuals to persuade and inspire people toward the achievement of common goals [Hecklau et al., 2016]. Some previously conducted studies have demonstrated that communication skills form one aspect of the generic aptitudes required for the employability and job-related success of fresh graduates because they equally benefit the employee and the organization [Morreale & Pearson, 2008; Conrad & Newberry, 2011]. The extant research has also shown that communication skills are deemed extremely important by academic faculty and administrators to the eventual career-based success of their students [Gray, 2010; Behn et al., 2012]. This competency also was addressed by the Accreditation Board for Engineering and Technology, European Network for Accreditation of Engineering Education: discrete accreditation systems most frequently repeated the terms “effective communication” or “the ability to communicate effectively” vis-à-vis the desired outcomes for students [ABET, 2017; European Network for Accreditation of Engineering Education, 2015].

TABLE 5.5 Comparison of Future Competencies for Three Demanding Careers of Industry 4.0

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Definition</th><th colspan="3">Required Competencies</th></tr>
<tr><th>Robotics Engineers</th><th>Data Scientists</th><th>Food Designers</th></tr>
<tr><td rowspan="8">Social Competencies</td><td rowspan="8">Skills and abilities as well as the attitude to cooperate and communicate with others</td><td colspan="3">★★★ Effective communication</td></tr>
<tr><td colspan="2">★★ Coordinating with others</td><td></td></tr>
<tr><td colspan="2">★★ Customer orientation</td><td></td></tr>
<tr><td></td><td colspan="2">★★ Storytelling</td></tr>
<tr><td>★★ Negotiation</td><td></td><td>★★ Negotiation</td></tr>
<tr><td>★ Team-building</td><td>★ Data visualization and presentation</td><td>★ Consulting</td></tr>
<tr><td></td><td>★ Teamwork</td><td>★ Partnering</td></tr>
<tr><td></td><td></td><td>★ Service mentality</td></tr>
<tr><td rowspan="6">Personal Competencies</td><td rowspan="6">Individual's social values, motivations, and attitudes</td><td colspan="3">★★★ Active learning</td></tr>
<tr><td colspan="3">★★★ Adaptability to change</td></tr>
<tr><td colspan="3">★★★ Leadership</td></tr>
<tr><td colspan="2">★★ Emotional intelligence</td><td></td></tr>
<tr><td>★ Patience and persistence</td><td>★ High integrity and ethics</td><td>★ Food designing expertise</td></tr>
<tr><td>★ Observing and curiosity</td><td>★ Heightened data intuition</td><td>★ Entrepreneurship</td></tr>
<tr><td rowspan="9">Methodological Competencies</td><td rowspan="9">Skills and abilities for general problem solving and decision making</td><td colspan="2">★★ Complex problem-solving</td><td></td></tr>
<tr><td colspan="2">★★ Critical thinking</td><td></td></tr>
<tr><td colspan="2">★★ Project management</td><td></td></tr>
<tr><td colspan="2">★★ Systems thinking</td><td></td></tr>
<tr><td>★ Creativity, originality, and initiative</td><td>★ Creative thinking</td><td>★ Understanding the contexts of food</td></tr>
<tr><td>★ Analytical thinking and innovation</td><td>★ Applicative thinking</td><td>★ Knowing the trends of food analytics</td></tr>
<tr><td>★ Design thinking</td><td>★ Associative skills</td><td>★ Food innovation thinking</td></tr>
<tr><td>★ Creative integration</td><td>★ Research skills</td><td></td></tr>
<tr><td>★ Time management</td><td>★ Business acumen</td><td></td></tr>
</table>

★★★ Competencies in demand for three types of jobs
★★ Competencies in demand for two types of jobs
★ Competencies in demand for each job

The ongoing sweeping transformations that are introduced into societies because of digitalization make adaptability to change a critical competence for youth who will become the employees of the future. They must be able to respond quickly to changing trends, innovations, destabilizations, industry shifts, and other unforeseen circumstances.

Moreover, prospective workers must quickly assess situations and learn what they need to make effective decisions. Continuing to learn new things can broaden one's experience and provide a person with more potential opportunities. Hence, active learning is recognized as an important competency for future employees in the long term, especially for those open to novel opportunities. Such individuals may be accorded access to a variety of career paths in the future.

Future employees in increasingly technology-driven and data-centered work environments will have to undertake more responsible tasks and must take on activities that are more related to decision-making and data analysis. Leadership skills would thus become the most recommended competency for every employee required to spearhead a team [Liboni et al., 2019].

Coordinating with others and customer orientation are competencies recorded in green to indicate that they must be inculcated in both robotics engineers and data scientists. Future workplaces will become more complex and will involve personnel spanning multiple generations and nationalities. The management of varying time-zones, work-patterns, and cultural attitudes given the impact of AI, and the coordination of divergent groups will become even more demanding than they currently are.

On the other hand, the competency of storytelling will become the common critically required competency for data scientists and food designers. Data scientists are extremely good with numbers; however, numerical skills are not sufficient on their own to convey outcomes of analyses to end-users. Being a good data storyteller ensures that the results of data analyses and modeling are accurately and legibly transmitted to the appropriate audience. The practice and application of storytelling also help food designers to create more compelling content to promote their businesses.

These results have demonstrated the existence of different requirements for competencies by the three occupation groups. Hence, the demands and needs of discrete industrial areas for competencies should be considered for the modification and reform of university education and curricula. Such changes should be based on frequent surveys that probe future societal and industry-related transformations because long-term technological and social developments of the future cannot be predicted.

5.8 Conclusion

The present study aimed to identify the competencies that are likely to be expected from those wishing to occupy three positions that are estimated to be in great demand in Industry 4.0: robotics engineers, data scientists, and food designers. These three professions are deemed to represent the projected requirements for high-skilled workers by Thai and multinational companies that currently form the vanguard of Thailand's growth industries. This study also underlined the significance of the crucial competencies for university graduates to become workforce-ready for the future. The following research questions were utilized to address this purpose:

Research Questions 1c: What are the future competencies for three high-skilled jobs in Industry 4.0: robotics engineers, data scientists, and food designers?

This study described the insights attained through a literature review, which was subsequently expanded through the intensive investigation of the required competencies through individual interviews with senior experts and focus group interviews with highly qualified managers and educators. After a consensus was achieved, a questionnaire survey and in-depth interviews were further conducted with selected specialists in the automotive, digital, and food industries and lecturers in related disciplines to confirm the essential future competencies of the three stated future careers. Finally, the robustness of the analysis was verified.

The findings revealed a diverse mix of demanded competencies in the current Industry 4.0 environment and will be desired soon. Industry 4.0 focuses predominantly on multidisciplinary tasks. Hence, effective communication, active learning, adaptability to change, and leadership should be inculcated in all three groups of graduates aiming to fill the emergent demand for the stated careers, and employees of the future should imbibe these competencies at advanced levels to work successfully in the Industry 4.0 era. The results of this study indicate that universities and higher education institutions must contemplate ways to inculcate the skill sets in demand within their graduates to prepare the youth for the world of work.

Asia is widely recognized as a hub that is pivotal for global economic growth. Therefore, the nations of this region must urgently explore crucial advanced technologies and changing competencies that could influence the future opportunities of university graduates. Mastery over new capabilities may accord a competitive advantage to the region's young graduates. The upskilling of other capabilities including social, personal, and methodological abilities before youngsters graduate from tertiary educational institutions can also open extensive opportunities for the region's graduates to compete with other, more experienced, candidates.

However, higher education institutions' training methods substantially influence students' abilities to develop competencies effectively. Hence, to ensure that this goal is reached, higher education institutions must brainstorm and investigate effective educational programs and methodologies to enhance the in-demand skillsets among its graduates and prepare them for future employment.

Industry 4.0, as previously reported, has resulted in a transition from a knowledge-based curriculum (with a focus on knowledge) to competency-based instruction (an emphasis on competencies). Creating an intergraded curriculum that provides potential competencies, for example, would provide students with opportunities for advancement within the work system after they graduate and continue working in the field, as these skills train them to be forward thinkers, which promotes upward mobility.

As a result, combining the importance of hands-on pedagogy with competency-based education is in the long-term best interests of both students and employers, and a competency-based model would emerge as an effective teaching platform for producing professional potential learners. Furthermore, incorporating competency-based education is thought to increase active and immersive teaching approaches. Not only students but also teachers, appear to have more options to control their actions in order to attain learning goals

Competency-based instruction should use instructional approaches that enable students to be self-directed learners, exercise what they have learned, and undergo educational opportunities that complement their learning style. Notably, these practices necessitate continued practice, as competency acquisition is a continuous phase [Robinson et al., 2015].

However, the present study was conducted for three job positions projected to be in demand in Thailand: robotics engineers, data scientists, and food designers. Therefore, the results represent an overall perspective of crucial competencies for these three future careers in the digital era and hold true to a limited organizational sample. The context of additional careers could be explored by future studies, which could also focus in more detail on the additional aspects and challenges of the current dynamic world. Future studies will be conducted by the authors of this investigation to intensively probe the competency requirements of organizations separated by business sizes and types. Prospective research endeavors will also attempt to identify the gaps between demand and supply.

Chapter 6

The Assessment of Generic Competencies of Thai Working Engineers using PROG Test

6.1 Background and purpose of the study

The technological transformation is affecting almost every area of the economy, society, culture, and environment. It was realized that business and industry have changed drastically as small and large firms alike have adopted advanced technological and total quality management practices. Firms across industries now demand broadly-trained employees with cross-functional competencies to compete in highly dynamic markets. Technological progress also has brought about growth in customers' sophistication and enhanced competitiveness. Today's employers are increasingly seeking generic skills alongside technical skills as a means of developing a workforce that can cope with: increasingly complex work practices; team working; reduced supervision; greater job flexibility and rotation and increased interaction with customers. Generic skills are important because present jobs need flexibility, initiative, and multitasking ability.

Governments and other stakeholders are increasingly interested in assessing the skills of their adult populations to monitor how well prepared they are for the challenges of the current knowledge-based society. Adults are expected to use information in complex ways and to maintain and enhance their literacy skills to adapt to ever-changing technologies. Literacy is important not only for personal development but also for positive educational, social, and economic outcomes.

The recent social, economic, and environmental trends pose new requirements to higher engineering education. For a decade, Industry 4.0 has triggered a notable educational challenge, bringing the need to create a new type of engineer, so-called T-shaped engineers. The T-shaped individual is a professional having both in-depth knowledge (the vertical part of "T") of at least one discipline and one domain and transversal knowledge and skills (the horizontal part of "T"); such as communication and collaboration within multidisciplinary teams, ability to work in a team, leadership, project management, critical thinking, systematic thinking, languages, adaptation and flexibility, multiculturalism, etc. The potential benefits of T-shaped engineers to organizational performance are quite significant; hence, the demand for T-shaped professional engineers in knowledge-intensive, service-oriented economies is increasing. The engineering community agreed that the concept of T-shaped is ideal for the training of engineering graduates for successful practice in the global economy. We can find the usefulness of the T-shaped concept everywhere and every field will require a T-shaped professional for development [Uhlenbrook & Jong, 2012].

Despite widespread agreement on the relevance of generic skills in engineering practices and engineering students, the research demonstrates a mismatch between employer expectations and the performance of new engineers. Hence, the need to inculcate the wide variety of knowledge and generic skills into graduates to meet these demands has been of concern to stakeholders in education and the world of work. However, the challenge of engineering education is not only to simultaneously prepare students for their first job but they need to prepare them for lifelong learning and career success.

In this study, we focused on measuring the generic competency of Thai working engineers as recent graduates using the Progress Report on Generic Skills (PROG) assessment tool to assess their current competency and to analyze the key factors of Thai engineers' competency development in their careers, as well as investigating the key generic competencies for preparing engineering students for professional engineering jobs and career success. The results of this study provide guidelines for producing T-shaped graduate engineers for the fast-changing industrial world and future work on the development and assessment of generic skills within the education of future engineering professionals.

6.2 Research Question

Research Question 1d: What are the key generic competencies for preparing engineering students for professional engineering work and career success?

Specifically, the objectives of this study are:

1) To measure the generic competencies of Thai working engineers;
2) To examine the critical components influencing Thai engineers' competency improvement throughout their careers;
3) To investigate the key generic competencies for preparing engineering students for professional engineering jobs and career success.

6.3 Generic skills in engineering education

The term generic is used to refer to attributes, competencies, or skills for graduates and working people across all disciplines. Generic skills which are also referred to as key skills or core competencies are significantly used in the present conversations in society, working life, and education [Virtanen and Tynjälä, 2018].

Generic skills have become an important focus of educational systems around the world. The main challenge of engineering education is to foster initial competencies that prepare students for their first job. Therefore, the responsibility of universities and institutions is to develop and embed these competencies in their engineering curriculum and determine specific learning outcomes for students.

From a detailed review of the research literature on generic skills in engineering, as shown in Table 6.1., [e.g., ABET, 2013; Hong Kong Institution of Engineers, 2013; Male et al., 2010, 2011; Passow, 2012; Scott & Yates, 2002; Spinks et al., 2006; Halliday, 2000; and Liu & Schonwetter, 2004], there are 12 domains of generic skills identified as important to the engineering context:

Table 6.1 Generic skills in engineering context

Generic skills	Definition
Interpersonal Skills	the ability to engage in the building and maintenance of relationships
Communication Skills	the ability to communicate effectively in a wide range of settings, both orally and writing
Teamwork Skills	the ability to work with others, particularly in multidisciplinary teams, which are common in the engineering working environment
Problem-solving Skills	the ability to identify, analyze, and solve engineering problems
Critical Thinking	the ability to think critically and independently as well as creatively
Self-Management	the ability to self-reflect, organize things, and manage time
Professional Effectiveness	the ability to understand professionalism in terms of professional conduct, ethics, and responsibility in engineering practices
Adaptability Skills	the ability to be flexible and to keep an open mind when facing unexpected situations and problems
Information Literacy	the ability to manage information by identifying relevant information and researching information
Leadership	the ability to play multiple roles of a leader in coordination and planning, motivating and supervising team members, and building team cohesion
Academic/Learning Skills	the ability to demonstrate and apply mathematics, science, and engineering knowledge and skills; for engineers, these skills include computer skills such as programming
Community and Citizenship Knowledge	the awareness of political, social, economic, and environmental issues

Interpersonal, communication, teamwork, and problem-solving skills are most frequently identified and rated as highly important by engineers [e.g., Male et al., 2011; Passow, 2012; Spinks et al., 2006]. Although there is general agreement on the importance of these skills in engineering practices and engineering students, nevertheless the literature reveals that a gap exists between the expectations of employers and the performance of fresh engineers.

6.4 PROG Assessment Tool

Progress Report on Generic Skills, so-called PROG, was launched in 2012 and it has been one of the most widespread assessment tools to measure learning outcomes of college students among institutions of higher education in Japan. 455 higher education institutions which are more than 1,000,000 Japanese students and the graduates in higher education institutions took this test by 2019 [Matsumura & Tanabe, 2019]. PROG is available in English, Japanese, and Thai language.

PROG aims to evaluate two elements of generic skills: literacy and competency. The term literacy is defined as the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals. Competency is recognized as the capability of using specific skills, abilities, and knowledge essential to successfully perform a specific task in a defined work setting. In PROG, as shown in Figure 6.1, literacy is defined as the ability to utilize knowledge (cognitive ability), which is composed of problem-solving skills set e.g. data collection, data analysis, problem-solving, and conceptual thinking skills. While competency is the action tendency and decision-making style derived from one's experience (non-cognitive ability), which is composed of three categories' essential skills set; teamwork skills, personal skills, and problem-solving skills that are also included in literacy. The components of PROG; literacy and competency, were identified as required generic skills by industry in Japan. As generic skills are crucially required for high-performing business leaders and work teams.

To measure the literacy and competency using the PROG test, 45 minutes are allocated for the Literacy section with 30 questions and 40 minutes for the Competency section with 195 two-alternative forced-choice questions, 30 short-situation questions, and 5 long-situation questions. PROG competency test is evaluated from level 1 to 7 for skills in literacy and competency parts. Assessment for literacy part indicates problem-solving skill based on the knowledge, while the competency part evaluates attributes for communication, self-management, and problem-solving.

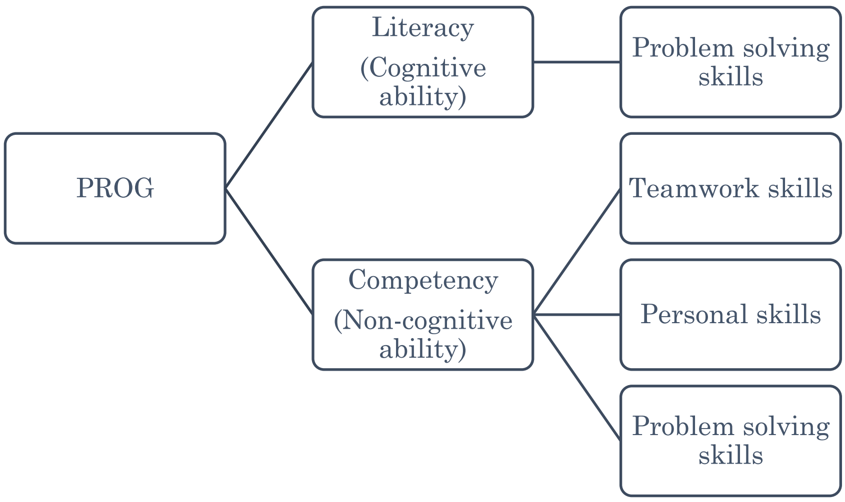

Figure 6.1 Components of PROG

6.5 Methodology

In this study, the aspect of competency was used to measure the current's competencies of Thai engineering workers and to analyze the key factors of Thai engineers' competency development in their future growth, and to provide guidelines for future work on the development and assessment of generic skills within the education of future engineering professionals. The result of competency was provided to the respondents by analyzing 3 categories, 9 components, and 33 elements (Fig. 6.2).

The survey was distributed to Thai working engineers in various fields and industry sectors. The survey was conducted from December 2020 to February 2021, and 107 Thai working engineers took this test.

The personal information survey contained questions related to demographics and employment such as age, gender, academic background, job category, job position, and industry sector. For the competences section, there are 195 two-alternative forced-choice questions, 30 short-situation questions, and 5 long-situation questions for approximately 40 minutes.

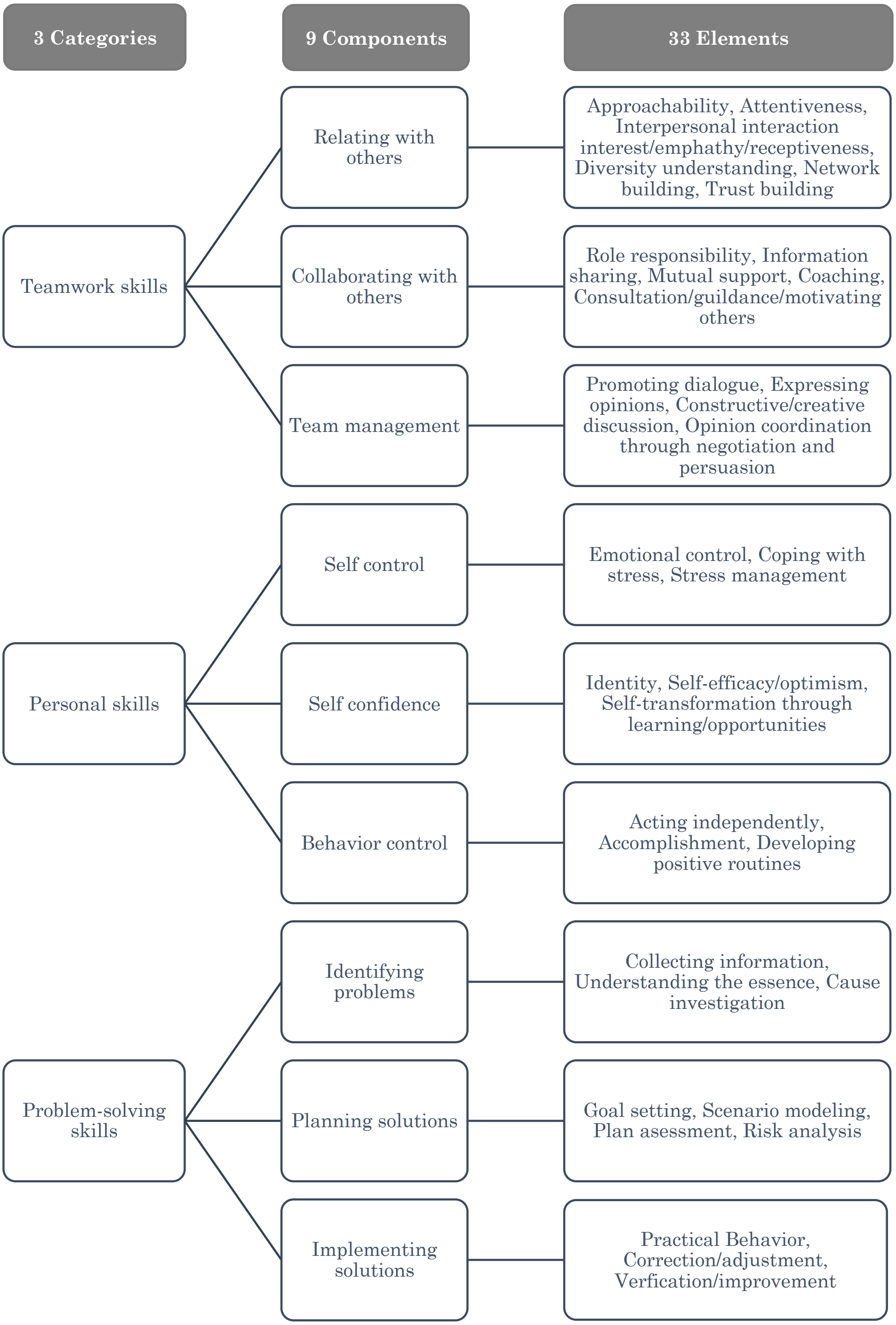

Figure 6.2 Skill categories, components, and element of PROG

6.6 Analysis and results

In this study, the respondents provided information regarding their age, gender, education degree, academic discipline, academic background, company's nationality, number of employees at their company, industry types, job category, and job position. Consequently, PROG competency results were analyzed to measure the generic competency of Thai working engineers, with consist of 3 categories, 9 components, and 33 elements, and to analyze the key factors of Thai engineers' competency development in their careers.

6.6.1 Characteristics of survey respondents

The majority (55.1%) of the respondents were in the 20–29 age group, 39.3% were in the 30–39 age group, 4.7% were in the 40–49 age group, and 0.9% were in the 50–59 age group, as shown in Table 6.2.

Table 6.2 Age groups of the survey respondents

Age group	Responses	Percentage
20-29	59	55.1
30-39	42	39.3
40-49	5	4.7
50-59	1	0.9
Total	107	100

The majority (76.6%) of the respondents were male, 22.4% were female, and 0.9% were other gender, as shown in Table 6.3.

Table 6.3 Gender of the survey respondents

Gender	Responses	Percentage
Male	82	76.6
Female	24	22.4
Other	1	0.9
Total	107	100

The survey respondents were asked to provide their education degrees. The majority (76.6%) of the respondents had completed a bachelor's degree, 22.4% had completed a master's degree, and 0.9% graduated vocational college, as indicated in Table 6.4.

Table 6.4 Education degrees of the survey respondents

Education degrees	Responses	Percentage
Master's degree	24	22.4
Bachelor's degree	82	76.6
Vocational college	1	0.9
Total	107	100

The survey respondents also provided their academic discipline. The majority (56.1%) of the respondents were engineering, 36.4% were computer science, 4.7% were business, and 0.9% were education. These results are shown in Table 6.5.

Table 6.5 Academic discipline of the survey respondents

Academic discipline	Responses	Percentage
Business	5	4.7
Computer science	39	36.4
Education	1	0.9
Engineering	60	56.1

Other	2	1.9
Total	107	100

The majority (92.5%) of the respondents took science and engineering, 2.8% took arts and humanities, and 4.7% took other academic fields, as shown in Table 6.6.

Table 6.6 Academic background of the survey respondents

Academic background	Responses	Percentage
Science and Engineering	99	92.5
Arts and Humanities	3	2.8
Other	5	4.7
Total	107	100

Subsequently, the survey respondents were asked to provide their company's nationality. As shown in Table 6.7, the majority (89.7%) of the respondents worked in Thai companies, 3.7% worked in United States companies, 2.8% worked in Japanese companies, 1.9% worked in Singapore companies, and 0.9% worked in United Kingdom company and a Chinese company.

Table 6.7 Company's nationality of the survey respondents

Company's nationality	Responses	Percentage
Thailand	96	89.7
Japan	3	2.8
China	1	0.9
Singapore	2	1.9
United States	4	3.7
United Kingdom	1	0.9
Total	107	100

The number of employees within the respondents' companies was also included in the survey. The majority (37.4%) of the survey respondents worked for companies with 100–299 employees, 29% worked for companies with 300–999 employees, 22.4% worked for small companies with fewer than 100 employees, 7.5% worked for companies with 1,000–2,999 employees, and 3.7% worked for companies with 3,000–9,999 employees, as shown in Table 6.8.

Table 6.8 Number of employees of the survey respondents

Number of employees	Responses	Percentage
Less than 100	24	22.4
100 to 299	40	37.4
300 to 999	31	29.0
1,000 to 2,999	8	7.5
3,000 to 9,999	4	3.7
Total	107	100

Next, the respondents were asked to identify the type of industry that most closely matched their current employment. The top five industries were IT, ICT, and IoT (44.9%), manufacturing, including machinery and electronics (24.3%), and manufacturing, including materials, chemicals, food, cosmetics, pharmaceuticals (13.1%), other (5.6%), and finance, transportation, logistics, energy, and public service (2.8%), as indicated in Table 6.9.

Table 6.9 Industry types of the survey respondents

Industry types	Responses	Percentage
IT, ICT, IoT	48	44.9
Manufacturing (e.g. Machinery, Electronics)	14	13.1
Manufacturing (e.g. Materials, Chemicals, Food)	26	24.3

Finance	3	2.8
Transportation, Logistics, Energy	3	2.8
Construction, Plant, Real estate	2	1.9
Entertainment, Tourism, Leisure	2	1.9
Public service	3	2.8
Other	6	5.6
Total	107	100

The survey respondents also provided their job category. The majority (21.5%) of the respondents were programmers, 19.6% were software engineers, 13.1% were mechanical engineers, 8.4% were production and quality control engineers, and 6.5% were sale engineers. These results are shown in Table 6.10.

Table 6.10 Job categories of the survey respondents

Job categories	**Responses**	**Percentage**
Systems engineer	3	2.8
Programmer	23	21.5
Software engineer	21	19.6
IT consultant	3	2.8
Sales engineer	7	6.5
Mechanical engineer	14	13.1
Electronic engineer	1	0.9
Electrical engineer	3	2.8
Production / Quality control engineer	9	8.4
Plant engineer	2	1.9
Construction / Civil engineer	2	1.9
Sales representative	1	0.9
Designer	2	1.9
Product developer / Marketer	3	2.8
Financial specialist	1	0.9
Other	12	11.2
Total	107	100

Finally, the survey respondents were asked to provide their job position. At the time of the survey, the majority 42.1% of the respondents were in a staff position, 17.8% were in a senior staff position, 12.1% were in supervisor/section chief, 5.6% were in manger and section manager, and 0.9% were in executive director and general manager. These results are shown in Table 6.11.

Table 6.11 Job position of the survey respondents

Job position	Responses	Percentage
Executive director	1	0.9
General manager	1	0.9
Manager	6	5.6
Section manager	6	5.6
Supervisor / Section chief	13	12.1
Senior staff	19	17.8
Staff	45	42.1
Other	16	15.0
Total	107	100

6.6.2 PROG competency results of survey respondents

In this study, we focused on measuring the generic competency of Thai working engineers as recent graduates using the Progress Report on Generic Skills (PROG) assessment tool to assess their current competency and to analyze the key factors of Thai engineers' competency development in their careers, as well as investigating the key generic competencies for preparing engineering students for professional engineering jobs and career success. To accomplish this goal, the following research questions were used:

Research Questions 1d: What are the key generic competencies for preparing engineering students for professional engineering work and career success?

The PROG competency results were analyzed to measure the generic competency of Thai working engineers, which consists of three categories, nine components, and thirty-three elements, and to analyze the key factors of Thai engineers' competency development in their careers, as well as to investigate the key generic competencies for preparing engineering students for professional engineering jobs and career success.

According to the findings, the highest level of skills possessed by Thai engineers are "Problem-solving skills" (M=5.13), "Personal skills" (M=4.94), and "Teamwork skills" (M=4.29), as shown in Table 6.12.

Table 6.12 PROG competency results of the survey respondents

Competencies	Mean	SD
Teamwork skills	4.29	1.43
• Relating to others	4.05	1.61
• Collaborating with others	4.76	1.41
• Team management	3.83	1.46
Personal skills	4.94	1.27
• Self control	5.23	1.46
• Self confidence	4.65	1.18
• Behavior control	4.35	1.30
Problem solving skills	5.13	1.53
• Problem identification	4.93	1.39
• Planning solutions	4.85	1.71
• Implementing solutions	5.09	1.42

As seen in Figure 6.3, the highest level of skill held by Thai engineers is "Self-control" (M=5.23), followed by "Implementing solutions" (M=5.09), "Identifying problems" (M=4.93), and "Planning solutions" (M=4.85), all of which are problem-solving abilities. "Team management" (M=3.83) is the lowest level of expertise.

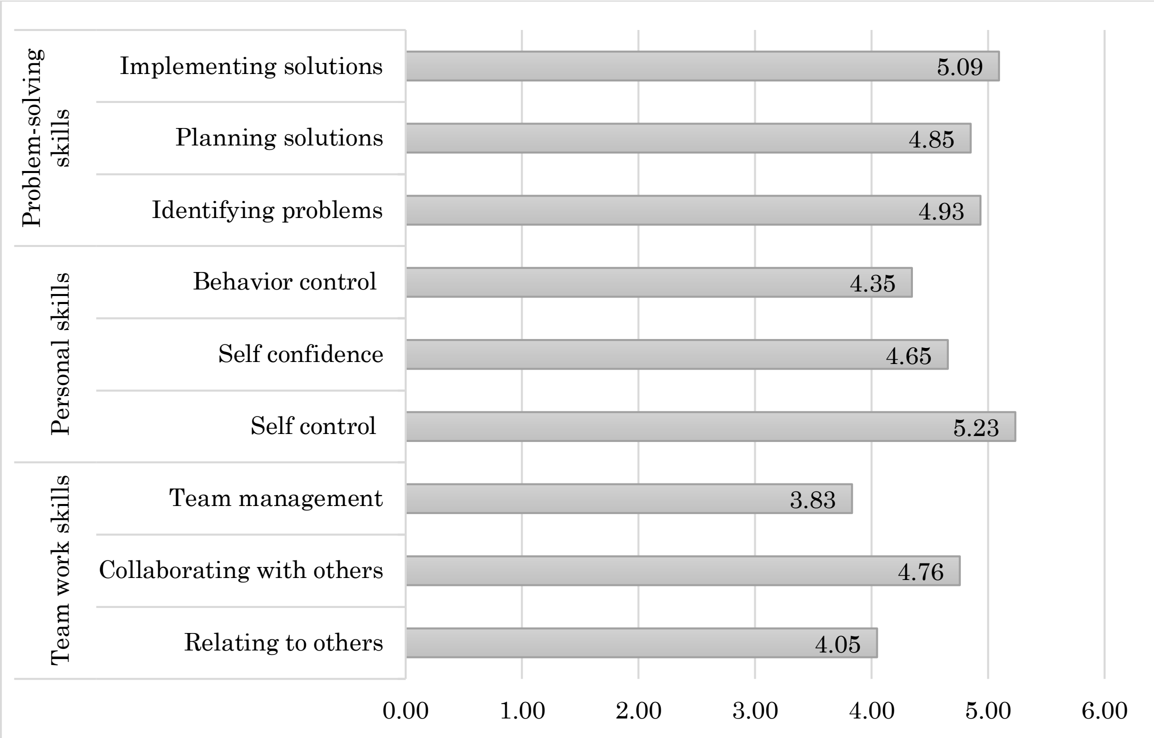

Figure 6.3 Competency level of Thai working engineers

Mean scores on the skills possessed by Thai working engineers were compared in 2 dimensions; job position and company size.

1) Job position

In comparison, Thai working engineers in managerial positions performed marginally better in all three components: "Teamwork skills," "Personal skills," and "Problem-solving capabilities." Thai working engineers in non-management positions, on the other hand, scored higher on “Behavior control” as a component of “Personal skills.”

Further analysis, based on independent samples t-test, was performed to test if there are significant differences in the competency level of Managerial positions and Non-managerial positions. Statistical significance was set at standard 95 percent.

As demonstrated in Table 6.13, there are statistically significant differences in the competency level of managerial positions and non-managerial positions in “Planning solutions” at the 0.05 significance level. Planning is a fundamental skill that forms part of executive functions and is described as the capacity to "think about the future" or mentally predict the best approach to carry out a task or achieve a specified goal. These findings imply that good leaders must be skilled in all aspects of planning, including goal setting, scenario modeling, plan assessment, and risk analysis, as well as make decisions, direct teams, and oversee all corporate responsibilities.

Table 6.13 Comparison of competency level by job position

Competencies	Managerial positions (n=27)		Non-Managerial positions (n=80)		T	P
	Mean	SD	Mean	SD		
Teamwork skills						
• Relating to others	4.37	1.71	3.94	1.57	1.24	0.22
• Collaborating with others	4.93	1.38	4.70	1.43	0.72	0.47
• Team management	3.93	1.36	3.80	1.50	0.38	0.70
Personal skills						
• Self control	5.48	1.40	5.15	1.48	1.02	0.31
• Self confidence	4.93	0.92	4.56	1.25	1.61	0.11
• Behavior control	4.30	0.99	4.36	1.40	0.27	0.79
Problem solving skills						
• Problem identification	5.33	1.14	4.80	1.44	1.74	0.08
• Planning solutions	5.74	1.23	4.55	1.75	3.88	**0.0002***
• Implementing solutions	5.41	1.34	4.99	1.45	1.33	0.19

* Significant at the .05 level

2) Company size

In comparison, Thai working engineers in small businesses scored higher in “Team management”, “Self control”, and “Self confidence”. Thai working engineers in medium-sized firms performed better in terms of “Relating to others”, “Collaborating with others”, “Behavior control”, “Problem identification”, and “Implementing solutions”. Thai engineers working in large companies, on the other hand, did somewhat better in “Planning solutions”.

Additional analyses were conducted to test if there are significant differences in the competency level of company size. Statistical significance was set at standard 95 percent.

As demonstrated in Table 6.14, there are statistically significant differences in the competency level of a small company, medium company, and large company in "Collaborating with others" at the 0.05 significance level. Small and medium company has the ability to collaborating with others more than employees in the large company because working in a small team helps them to increase engagement, make more effective communication and stronger support network and collaboration. Moreover, smaller teams allow for greater accountability, autonomy, and flexibility, both in terms of scheduling and idea-based changes. They foster greater trust among team members and less fear of failure.

Table 6.14 Comparison of competency level by company size

	Small Company (n=24)		Medium Company (n=71)		Large Company (n=12)		F	P
Competencies	Mean	SD	Mean	SD	Mean	SD		
Teamwork skills								
• Relating to others	4.08	1.47	4.11	1.68	3.58	1.62	0.56	0.57
• Collaborating with others	4.71	1.27	4.87	1.45	4.17	1.40	4.90	***0.01**
• Team management	4.04	1.49	3.82	1.48	3.50	1.38	0.55	0.58
Personal skills								
• Self control	5.50	1.59	5.21	1.40	4.83	1.59	0.85	0.43
• Self confidence	4.83	1.46	4.63	1.11	4.42	1.00	0.52	0.59
• Behavior control	4.38	1.21	4.45	1.30	3.67	1.44	1.90	0.16
Problem solving skills								
• Problem identification	4.79	1.32	5.04	1.38	4.58	1.62	0.72	0.49
• Planning solutions	4.88	1.80	4.83	1.71	4.92	1.68	0.02	0.98
• Implementing solutions	5.13	1.73	5.18	1.29	4.50	1.51	1.19	0.31

* Significant at the .05 level

However, the findings indicate that Thai working engineers in all positions and companies of all sizes scored worse in terms of "Team management skills." Team management refers to a manager's or organization's ability to lead a group of people in completing a task or achieving a common goal. Effective team management is encouraging, interacting with, and supporting team members so that they may perform to the best of their ability and continue to improve as professionals.

Thailand is one of the ASEAN countries where Buddhism is practiced by the majority of the population. Buddhism has strong roots in Thai culture and has a direct impact on their managerial style. Thai management places the most emphasis on harmony in business. In their organization, they always aim to prevent squabbles and disagreement. It is a phenomenon that affects providing orders, creating objectives, and making judgments based on top bosses/managers' directives. Because business in Thailand is more formal than in many Western nations, foreign managers operating in Thailand will most likely need to modify their management style in order to lead effectively [Chaidaroon, 2003; Chong, 2008; Malikhao, 2017].

In general, team management style of Thais, like that of many other Asian nations, is inspired by the notion of hierarchy. Thais place a high value on courtesy and respect for elders and those in positions of power. They are taught to respect superiors, parents, teachers, and the elderly from a young age. Many Thai workers, in particular, have learned not to raise questions. As a result, in Thailand, management style frequently results in employees who do not inquire, question, or confront. It is difficult to elicit their critical thinking and leadership since they do not want to be deemed impolite. However, if they work for a manager/boss who can encourage and promote teamwork to increase productivity, employees will feel less isolated and more involved with their job [Pandey and Chairungruang, 2020]. Thai employees may be highly hardworking and committed to completing the task. Having techniques in team planning and management, on the other hand, is useful for enhanced human resource management.

According to the previous study (Chapter 3), which highlighted the necessity of equipping engineering graduates with global competencies, indicated that well-known Thai and Japanese companies rate the ability to work in an international team as an essential competency for engineering students, as the result of well-known Thai companies tend to value global competencies because Thailand has an open market-oriented economy and encourages international direct investment as a means of promoting economic development, employment, and technology transfer. Thailand continues to welcome international investment and seeks to avoid dependence on any specific country as a source of investment. Therefore, the develop skill sets that enable employees to compete in an ever-expanding global environment, such as multidisciplinary teamwork skill, is required [Rawboon et al., 2021].

As engineers increasingly need to be able to work in cross-disciplinary teams to solve problems and pursue opportunities [Engineers Australia, 2019], and cross-disciplinary skills are needed to address the new challenges engineers face in their learning and work [Hadgraft & Kolmos, 2020], hence, communication, collaboration, and teamwork skills are increasingly seen as important components of engineering work [Trevelyan, 2014] and engineering education programs as well [Borrego et al., 2013; Hadgraft & Kolmos, 2020; Male et al., 2010, 2011; Paretti et al., 2014]. Moreover, accreditation bodies consider the ability to both lead and work in teams as an important outcome for engineering graduates [Engineers Australia, 2017].

Although there is clear evidence to support the importance of teamwork skills in engineering education, however, significant evidence reveals that many engineers fall short of meeting these industry requirements and the gap between the industry and academia is still there. Therefore, preparing engineering students to be effective in a future workplace, engineering education systems should aim at improving engineering programs and providing an accurate systems-approach to future engineers. Engineering programs must contemplate ways to inculcate interdisciplinary teamwork skills, as increasingly seen as an important component of engineering education programs, within their graduates to prepare the youth for the world of work.

6.7 Conclusion

This research aimed to measure the generic competency of Thai working engineers as recent graduates using the Progress Report on Generic Skills (PROG) assessment tool to assess their current competency, which consists of three categories, nine components, and thirty-three elements, and to analyze the key factors of Thai engineers' competency development in their careers, as well as investigating the key generic competencies for preparing engineering students for professional engineering jobs and career success. To accomplish this goal, the following research questions were used:

Research Questions 1d: What are the key generic competencies for preparing engineering students for professional engineering work and career success?

Thai working engineers in managerial positions outperformed in all three components: "Teamwork skills," "Personal skills," and "Problem-solving skills," according to the findings. However, at the 0.05 significance level, there are statistically significant differences in the skill level of managerial and non-managerial positions in “Planning solutions.” According to these findings, strong leaders must be skilled in all parts of planning, including goal setting, scenario modeling, plan evaluation, and risk analysis, in addition to making choices, directing teams, and overseeing all corporate tasks.

Furthermore, there are statistically significant variations in the competency level of a small, medium, and large company in “Collaborating with others.” Employees at small and medium-sized businesses have a greater capacity to collaborate with others than employees in large corporations because working in a small team allows them to increase engagement. make more effective communication, as well as a better support network and collaboration. Furthermore, smaller teams provide greater responsibility, autonomy, and flexibility in terms of scheduling and idea-based modifications. They increase team members' trust and reduce their fear of failure.

However, the findings indicate that Thai working engineers in all positions and companies of all sizes scored worse in terms of "Team management skills." Team management refers to a manager's or organization's ability to lead a group of people in completing a task or achieving a common goal. Effective team management is encouraging, interacting with, and supporting team members so that they may perform to the best of their ability and continue to improve as professionals.

Although there is clear evidence to support the importance of “Teamwork skills” in engineering education, as highlighted from the previous research (Chapter 3) that well-known Thai and Japanese companies rate the ability to work in an international team as an essential competency for engineering students, however, significant evidence reveals that many engineers fall short of meeting these industry requirements and the gap between the industry and academia is still there.

Therefore, to prepare engineering students to be effective in a future workplace, engineering education systems should aim at improving engineering programs and providing an accurate systems approach to future engineers. As the future workplace focuses predominantly on multidisciplinary tasks and employees of the future should imbibe these competencies at advanced levels to work successfully in the Industry 4.0 era, hence, engineering programs must contemplate ways to inculcate multidisciplinary teamwork skill, as increasingly seen as an important component of engineering education programs, within their graduates to prepare the youth for the world of work.

Chapter 7

An Integrative Learning Approach for Fostering Professional Competency in Engineering Education

7.1 Background and purpose of the study

Curricula designed in the context of engineering education need to be based on both domain-specific and professional competencies. Whereas universities have had extensive experience in developing students' domain-specific competencies, fostering professional competencies poses a new challenge we need to face.

The previous research has studied and surveyed professional skills and competencies that will be required of graduate professional engineers in the future. The required key skills and competencies have been identified and reported in chapters 3-6. Hence, to meet those needs and achieve these goals, engineering education should make many efforts to improve teaching quality to provide graduates and professionals with the necessary skills and competencies for success. One major development has been transforming teaching and learning from lecture-based to learner-centered, focusing on improving knowledge, skills, and approaches to teaching or students' perceptions of, and approaches to learning and learning outcomes.

Adopting an active learning approach to improve the performance of engineering students in higher education is becoming highly important. Active learning is a student-centered approach, which promotes students' engagement via applying different teaching strategies that motivate the students to become more involved in the learning process, either individually or collectively. The key active learning goal is to bring students into problem-solving, especially in complex situations that require collaborative efforts, joint reflecting on, and negotiating about the strategy and intended outcomes. Among the array of active learning approaches, STEAM is one of the recognized educational approaches for supporting engineering students to realize the world comprehensively and encourage them to develop their innovative ability to solve real-world problems [Anisimova et al., 2020; Psycharis, S., 2018]. While project-based learning (PBL) is a useful instructional methodology for addressing the learning outcomes [Felder & Brent, 2003] and providing the competencies needed for the sustainable development of education [Thomas, 2009]. The combination of STEAM and PBL has the potential to stimulate all aspects of engineering students' development holistically.

Hence, this study examines the use of an integrative learning approach, which is called STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education, and presents a STEAM-PBL framework with three interrelated dimensions: (1) the learning approach, (2) the social approach, and (3) the content approach. This study also presents some examples of engineering programs in two Asian universities, King Mongkut's University of Technology Thonburi (KMUTT) in Thailand and Shibaura Institute of Technology (SIT) in Japan, where the professional skills and competencies of students are developed through an integrative learning approach which university-industry collaborations model and various pedagogies that have the potential to support the delivery of the T-shaped engineering graduate and the greater breadth of graduate outcomes that will be required in future.

7.2 Research Question

Research Question 2: What is the most effective integrated learning approach for achieving professional competency in engineering education?

Specifically, the objectives of this study are:

1) To examines the use of an integrative learning approach, which is called STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education;
2) To presents a STEAM-PBL framework;

3) To presents some examples of engineering programs in two Asian universities.

7.3 STEAM-based education

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education emerged as a new pedagogy during the Americans for the Arts-National Policy Roundtable discussion in 2007, in response to the need to increase student interest and skills in Science, Technology, Engineering, and Mathematics (STEM) fields [Quigley et al., 2017]. STEAM education merges the arts with STEM subjects to improve student engagement, creativity, innovation, problem-solving skills, and other cognitive benefits [Hetland & Winner, 2004; Root-Bernstein, 2015], and to improve employability skills (e.g. teamwork, communication, adaptability) necessary for career and economic advancement [Colucci-Gray et al., 2017].

The combination of theory and practice to solve practical problems is an important way to cultivate students' innovative ability. Finding problems from life, and using the knowledge learned to design projects and solve problems requires students' innovative thinking. The cultivation of innovative ability is an important goal of STEAM.

The development of STEAM education requires the participation of teachers, community, and industry from different professional backgrounds. STEAM-based education is the construction of a social education ecological environment. From "school teaching community" to "social teaching community" should be a development trend. It is the combination mode of enterprise, university, and scientific research institute.

7.4 Project-based learning (PBL)

The term PBL has been defined in various ways. To emphasize a problem, PBL may refer to “an instructional learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” [Savery, 2015].

Despite the array of definitions and differences across PBL models, Kolmos and De Graf (2014) provide a comprehensive discussion of the development, range, and dimensions of PBL in engineering education and three underlying learning principles:

1. The learning process which involves working with problems organized through projects and case studies;

2. The social approach which covers team-based learning and participant-directed learning;

3. The content approach which covers the selection of knowledge and skills.

PBL is both a philosophy and a pedagogy guiding the practice of teaching and learning in engineering education. From a social constructivism perspective, learners generate meanings through participating in and engaging with activities rather than merely listening to lectures and memorizing the “right” answers [Jonassen, 2011]. Relying on learners’ prior experiences and using a problem as the starting point of a learning process facilitate cognitive development (De Graaff & Kolmos, 2003). Within a timeline, learners work on a unique task (project) that may be complex and contextual, applying theory to practice in an analytical approach within and beyond a discipline. From a socio-cultural perspective, PBL highlights learners’ engagement in activities and their co-constructed understanding through an interactive process [Savery, 2015]. Thus, through working in a team, learners develop strategies and collective engagement through collaborative learning, which demands sense-making, dialogue, interaction, and constructive communication.

7.5 An integrative learning approach: STEAM project-based learning (STEAM-PBL)

STEAM project-based learning, based on constructivist teaching theory, integrates interdisciplinary knowledge of science, technology, engineering, arts, and mathematics through project-based learning strategies; provides students with a learning situation in which they can actively explore real-experiences and design solutions to real-life problems to foster creative thinking and hands-on skills; adopts diversified evaluations so that students can give full play to their talents; exposes students to engineering-related science and technology, and enables students to interconnect their classroom with the real world.

STEAM will be more optimal if integrated with project-based learning, as crucial skills and competencies are covered through STEAM project-based learning. The evidence shows that the combination of STEAM and PBL has the potential to stimulate all aspects of engineering students' development holistically.

In this study, we investigate the application of an integrated learning approach known as STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education, as well as offer a STEAM-PBL framework and some instances of engineering programs at two Asian institutions. The following research questions were utilized to achieve this goal:

Research Questions 2: What is the most effective integrated learning approach for achieving professional competency in engineering education?

This research presents a conceptual framework based on learning theories and pedagogies that will lead to the achievement of important learning goals. The proposed conceptual framework for integrated STEAM project-based learning is depicted in Figure 7.1.

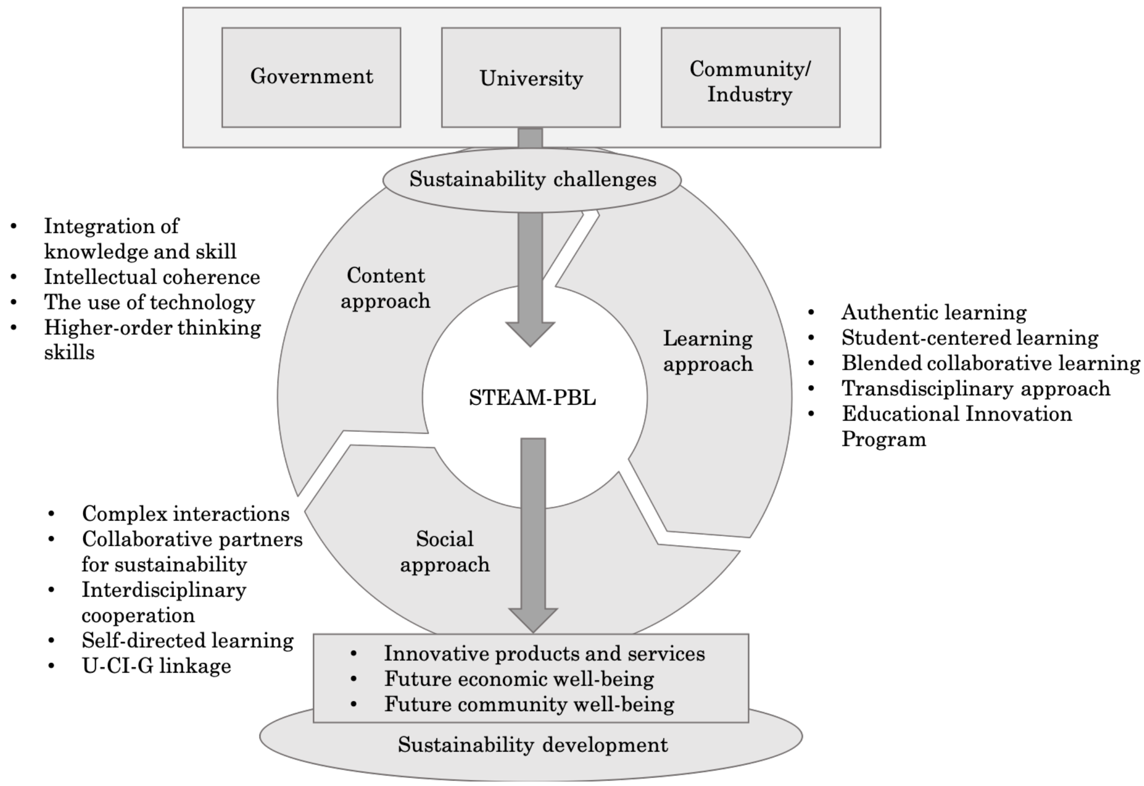

Figure 7.1 A conceptual framework of STEAM-PBL

Figure 7.1 demonstrates the role of the university in sustainable development. Educational institutions have the potential to provide specific knowledge which will be transformed into social skills. Especially, universities are cooperating strongly with organizations located in the same region. The universities can act as facilitators for sustainable development at the regional level, promoting innovation in society.

Since social learning becomes an increasingly significant strategic component within the context of sustainable development and environmental management (Keen et al., 2005). Universities are crucial in bridging the gap between government and society. Universities can induce collaboration between stakeholders to enhance the management of human and environmental interrelations. While the government can encourage the university to cope with these challenges with the support for managing the education system and contributing to policy-making.

A detailed description of the conceptual framework with three interrelated dimensions is also described. The learning approach is defined as a learning process of working with problems, which involves identification, analysis, and solution. Real-life problems and authentic problems enable students to have an authentic learning experience. These problems then form the starting point and the purpose for the learning process. A focus on 'real-world' problems in authentic contexts allows for the widest range of learning outcomes that span from that of simple awareness to the deeper learning inherent in the complexity of the real-world.

Secondly, the social approach is defined as a learning process of social acts and also covers team-based learning, in which learning takes place through dialogue and communication. This approach is grounded in self-directed learning, which indicates collective ownership of the learning process and especially the identification of the problem.

Finally, the content approach focuses on the integration of knowledge and skills through STEAM disciplines, which encourage students to apply theories from multiple subjects to solve a problem that uses technology, and connection to real life which lead to fine outcomes, such as, higher-order thinking skills and professional competencies.

The opportunities for interdisciplinary cooperation allow the development of individual skills, through PBL as an appropriate educational tool to generate a professional experience that strengthens experimental learning and relations with the collaborative partners and local community, links with governments, dealing with real and practical life issues, and actual experiences as learning situations, developing students' skills and competencies and promoting global and international project management skills.

The Asian university, namely, King Mongkut's University of Technology Thonburi (KMUTT), Thailand has implemented STEAM-PBL programs under KX BUILD division. STEAM-PBL program aims to prepare university's students and corporate personnel to deal with real-world business problems and challenges with the engineering design process through industrial collaborations.

The seven steps of STEAM-PBL, which led the students through the process of solving a real-life problem during each project, encourages student engagement, exploration, explanation, extension, and evaluation through design thinking. STEAM project-based on learning model was used to define the problem, explore and identify, brainstorm and select, develop and prototype, test and evaluate the results, make the change to the model, and show and share out the results. In each process, teachers played an important role as facilitators while students worked collaboratively to complete the project. The steps of the project based on the learning approach can be seen in Figure 7.2.

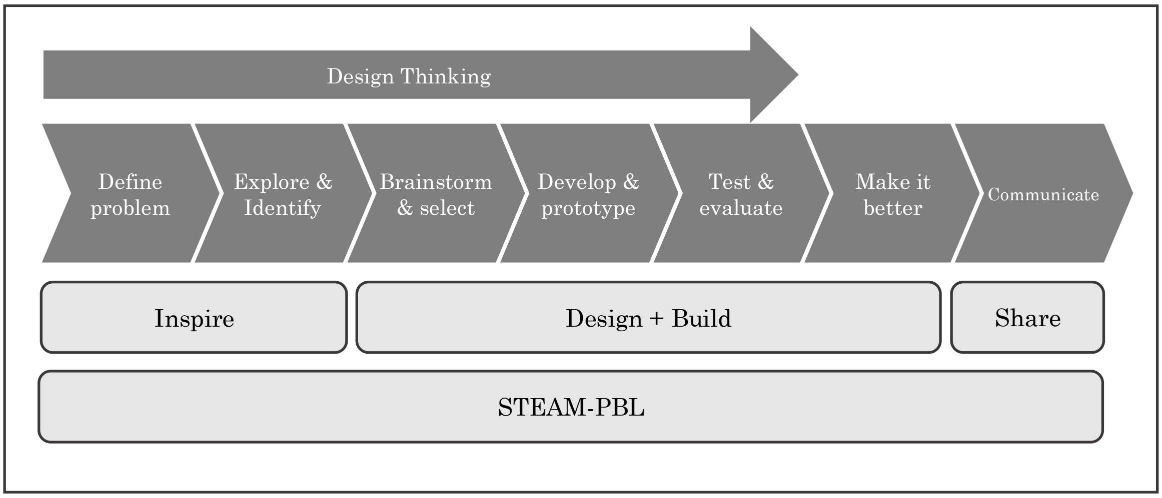

Figure 7.2 Steps for STEAM Project Based Learning

Step 1 Define the problem

To make learning relevant, students are presented with a problem provided by a real organization, with a real need for help. After that, students critically review and identify a problem statement (Fig. 7.3).

Figure 7.3 Students defining the problem

Step 2 Explore and identify

Students need to research at this stage for exploring related information by asking the question "What are constraints for creating a successful solution?" After that, they are encouraged to make a customer journey map, conduct persona research, define customer touchpoints, and identify the important factors for solving the problem. In this step, students are able to upload and share information with the entire class or specific group members; thus, all students can benefit from their peers' research (Fig. 7.4-7.5).

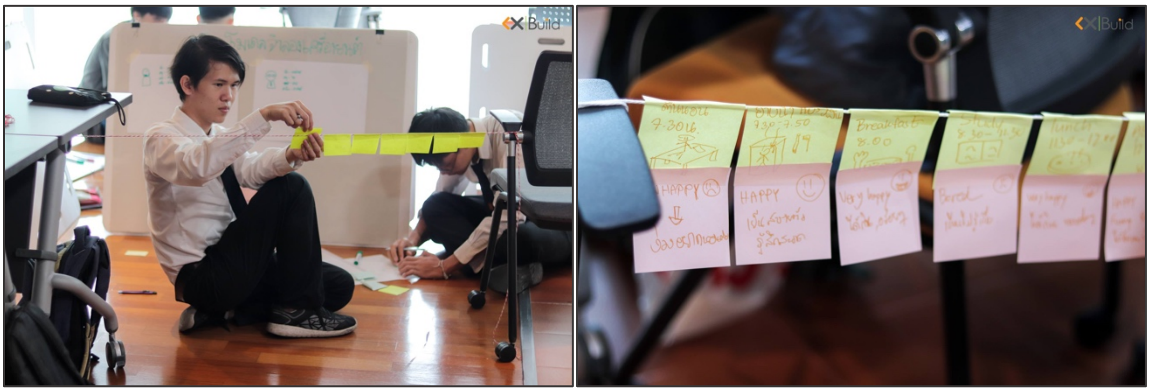

Figure 7.4 Students creating a user journey map

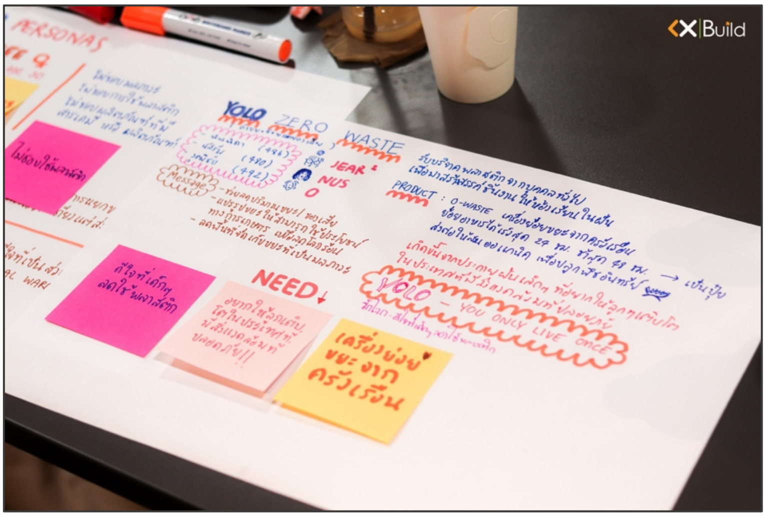

Figure 7.5 Students identifying important factors for solving the problem

Step 3 Brainstorm and select

After identifying the problem, students determine what they know and what they need to know and devise a plan to acquire the necessary information. As shown in Figure 7.6, the teacher can act as a facilitator during the brainstorming phase by reiterating the questions of "What do we know?" or "What do we need to know?" After brainstorming, students will make a list of possible solutions and select the best solution to explore (Fig. 7.7).

Figure 7.6 The teacher acting as a facilitator by reiterating the questions

Figure 7.7 Students brainstorming for making a list of possible solutions and selecting the best solution to explore

Step 4 Develop and prototype

Once students determine what they need to know, they assign research topics and research all necessary components. In this step, students will make a list of materials needed, draw a sketch and diagram, list the design process steps, and create a prototype (or build a model) of the possible solution (Fig. 7.8).

Figure 7.8 Students building a model of the possible solution

Step 5 Test and evaluate

In this stage, students test the prototype or model that students created by asking, "Does this solution solve the problem?" and analyze the results and also show how they came to this conclusion. This stage allows for all details to be flushed out and refined to create the best solution possible.

Step 6 Make it better

Once students generated ideas and developed a rationale to support them, they had the opportunity to share their ideas with an expert. Acquiring feedback from experts, students had the ability to reflect on their designs and to make improvements as desired. They will make the changes to the model or prototype to better solutions for the problem and make sure to test and evaluate the model again.

Step 7 Communicate

After building a scale model, the students played a leading role as, group by group, they presented their design ideas and applied STEAM-related knowledge while sharing the problems they encountered during the process, as well as their solutions. Students share their models regarding how they came to the solution for the problem and explain how their model solves the problem to the teacher, classmate, and organization (Fig. 7.9).

Figure 7.9 Students sharing and explain how their model solves the problem

The seven-step process identified in this program not only provides students with a systematic process of how to solve a real problem but also provides teachers with various opportunities to assess student learning. By collecting evidence, formally and informally, throughout each step of the engineering design process, teachers were able to assess student reasoning, strategies, procedures, and professional engineering skills.

Student learning can be evaluated through observations, one-on-one talks, discussions with project specialists, hand sketches, computer drawings, computation sheets, PowerPoints, models, and replies to open-ended questions such as "What did you learn?" and "How did you apply STEAM?" Student progress was visible at each stage of the project, such as at the conclusion, when each group presented a prototype model and a final PowerPoint presentation of their work.

This study integrates student responses to open-ended questions such as "What did you like?" received through student reflection at various stages during the seven processes, as well as final remarks were given by students on PowerPoint slides during their final project presentations such as “I liked how this project required a lot of thought and creativity. This assignment required us to use all of our brains and then combine them to discover answers.”

Students commented on how they liked having the ability to come up with their designs. Observing students work during the design process, reviewing student ideas expressed through hand sketches and other mediums, and reading student comments about what they learned and what they liked about the project, it became apparent that students not only learned STEAM but also were motivated by having a sense of empowerment as they engaged in the project (Fig. 7.10).

Figure 7.10 Student reflection in various points of the seven phases

The overview of remarks, as well as individual quotes, presented in this study, are representative of the majority of students and demonstrate how the numerous initiatives provided possibilities for students to become inspired and involved. With design-focused projects, students were empowered through support and ongoing encouragement to identify problems, brainstorm, generate ideas, devise their creative solutions, select choices, and make changes as necessary. While each project was different, student consensus was that they recognized how they were in control of their learning and appreciated having the ability to make their own decisions.

Many researchers are convinced that STEAM education contributes to students' acquiring professional skills in problem-solving, critical thinking, collaboration, communication, management, creativity and innovation, systematic thinking, analytical thinking, and self-directed learning as well as a connection to real-world problems [Colucci-Gray et al., 2017; Perignat & Katz-Buonincontro, 2018; Shatunova et al., 2019].

Communication is one of the crucial skills for establishing interpersonal relationships and is needed in the 21st century [van Laar, et al., 2019]. Communication skills are challenging when people from different disciplines must work together to achieve a common goal. Consequently, this study aims to examine the effect of integrative learning approach based on PBL integrated STEAM on communication skills by presenting some examples of engineering programs in two Asian universities, King Mongkut's University of Technology Thonburi (KMUTT) in Thailand and Shibaura Institute of Technology (SIT) in Japan, where the professional skills and competencies of students are developed through STEAM education and an integrative learning approach, such as project-based learning, problem-based learning, work-integrated learning (WIL), which university-industry collaborations model.

7.6 Professional Communication Education through Academia–Industry Collaborations: Some Examples at Two Asian Universities

Developing effective communication skills in students is an essential component of the engineering curriculum to prepare them for their future careers. However, various studies have indicated that engineering graduates tend to have poor communication skills [Benefield et al., 1997; Downing, 2001; Fromm, 2003; Meier, 2000; Prados et al., 2005]. Professional communication skills help students to develop their workplace skills and enhance their marketability and employability [Riemer, 2007; Polack-Wahl, 2000; Keane & Gibson, 1999]. Engineers have to communicate on a daily basis with fellow engineers, with supervisors, with people from different departments, and even with clients. Professional communication in engineering is often critical for ensuring that all the project stakeholders understand the objective and approach of the project. At present, employers are increasingly emphasizing the requirement for students to acquire professional communication skills for enhancing their community engagement, increasing their motivation leading to not only academic success but also a successful career after graduation.

The criteria for accreditation by the Accreditation Board for Engineering and Technology (ABET) require that communication skills should be integrated into engineering programs and that the outcomes of these programs should be assessed [Prados et al., 2005]. However, professional communication is not often discussed while developing an engineering curriculum. This study was conducted to answer the following two research questions: 1) what are the important elements in professional communication that should be inculcated in the engineering students by engineering programs? 2) what are the effective methods to integrate professional communication into engineering programs to enhance the program?

7.6.1 Importance of professional communication skills

Several employers consider communication skills as an essential component of a professional engineer's skill set, especially for an engineer who desires to work on international projects. In the workplace, employers often look for people who can demonstrate a good set of transferable skills, such as communication, problem–solving, and teamwork [Raftopoulas, 2009; Raybould & Sheedy, 2005]. Morreale et al. denote that effective communication skills are especially important while working in teams with members from different cultural backgrounds and while engaging in problem-solving and conflict management [Morreale et al., 2000]. The study also indicates that the majority of the jobs require professional communication skills, which is one of the essential career competencies that graduate students must possess. In his book, Rochford comments that knowledge, attitude, and skills are required to communicate effectively and appropriately [Edlin, 2011]. It has been stated that communication should be fostered in engineering education, not just because they are qualities that employers look for but because they should be part of any tertiary education [Beder, 2000]. Therefore, professional communication skills should be integrated into the undergraduate curriculum [Musselman, 2010]. Based on recent observations, the engineering curriculum has made efforts to include professional communication skills in their undergraduate programs. For instance, classes and curricula are starting to implement interpersonal and social interactions through a project–based learning, teaching activities, group work [Andersson, 2009]. To design a curriculum that bridges the gap, educators need to know which communication skills are expected in the workplace.

7.6.2 Communication elements

Various professional communication skills need to be considered when examining the engineering curriculum. The following is the list of skills each engineering student should strive to achieve:

Oral communication skills

Oral communication skills are considered important in the graduates' new work environment [Polack-Wahl, 2000]. Oral presentation skills are also one of the best "career enhancers" that students can add to his/her collection of marketable skills [Cohen & Jensen, 1995]. The ability to communicate effectively, both verbally orally, and in writing is one of the desirable skills and attributes of an engineer [Nyugen, 1998].

Written communication skills

Writing skills are an important part of communication. A variety of reports identify written communication skills as an essential workplace skill than any professional or technical skills [Gray et al., 2005]. Written communication includes engineering reports, technical writing, essays, reflective journals, peer review, and mock and student conference papers.

Listening skills

Listening is the ability to accurately receive and interpret messages in the communication process. Listening is the key to all effective communication. In addition to active listening, you must also allow the speaker to finish their thought in its entirety. Reflecting is the process of repeating and paraphrasing both the feelings and words of the speaker to show that they truly understand what the speaker is saying [Types of Listening Skills With Examples].

Questioning skills

Questioning is a crucial skill to get more information and to achieve a deeper understanding. Asking a question is fundamental to successful communication. Asking the right question is at the heart of effective communication and information exchange.

Non-verbal communication

Non-verbal communication is the process of sending and receiving messages without using words, either spoken or written. It is also called standard language. Many people communicate with more than just words when they interact with other people; their body language has a style of its own.

Visual communication skills

Visual communication skill is the sharing thoughts ideas or insights using visual aids such as drawings, illustrations, photographs, symbolic pictures, diagrams, pictograms, etc.

Research suggests that visual aids support experiential learning in a project–based interdisciplinary communication course where students must demonstrate their understanding of the concept [Jarmon et al., 2009].

Interdisciplinary communication skills

Interdisciplinary communication skills are being increasingly recognized as essential skills for engineering graduates, especially graduates who intend to work in internationally. Engineers need to communicate and work with fellow engineers from other countries. It has been identified that interdisciplinary communication skills can help to build a strong working relationship among team members and create a positive working environment.

Intercultural communication skills

Nowadays, we meet people from different cultures. Engineers need to communicate with people from different cultural backgrounds both in domestic and international settings as well as across a variety of contexts. It has been shown that intercultural communication skills enable students to adjust to different cultures and to deal with different social systems [Spitzberg, 1994].

Empathy

Empathy is the ability to understand other people's minds—their intentions, beliefs, and feelings. Empathy is vital to gain trust, which is the key element to build strong relationships.

Team leadership

Good leadership skills are important in the workplace. A team leader is someone who provides guidance, instruction, direction, and leadership to the team for the purpose of achieving a certain goal. Zaccaro et al [Zaccaro, 2001] demonstrated that leadership skills could influence team effectiveness by their effect on four sets of team processes—cognitive, motivational, affective, and coordination.

Emotional intelligence

Emotional intelligence is the ability to accurately perceive emotions, to access and generate emotions so as to assist thought, to understand emotions and emotional knowledge, and to reflectively regulate emotions so as to promote emotional and intellectual growth [Mayer et al., 2004]. Emotional intelligence (EI) can be divided into two personal and social competencies [Goleman, 2001].

7.6.3 The working mechanism of academia–industry collaborations program

This study presented some examples of engineering programs in two Asian universities, namely, King Mongkut's University of Technology Thonburi (KMUTT) in Thailand and Shibaura Institute of Technology (SIT) in Japan, where develop professional communication skills of students are developed through university–industry collaborations.

Both KMUTT and SIT have implemented educational programs through industrial collaborations to prepare students to deal with globalization and the ever–expanding innovation ecosystem. Many graduates from both universities pursue their career in multinational companies that promote the globalization of technological innovation. Graduates are often employed to become managers in the future who will lead engineering projects or oversee teams, particularly, global projects involving diverse professionals. Therefore, the importance of professional communication education has been increasing in both universities.

At KMUTT, Work Integrated Learning (WIL) Program, Innovation and Technology Assistance Program (ITAP), and Talent Mobility (TM) Program are being implemented. At SIT, Project–based Learning (PBL) courses are implemented in collaboration with industries and local communities to provide practical engineering and communication skills to students.

7.6.3.1 Work-integrated learning (WIL)

WIL program can be defined as educational programs which combine and integrate learning and its workplace application, regardless of whether this integration occurs in industry or the university and whether it is real or simulated [Atchison, 2002]. The aim is to ensure that students develop the ability to integrate their learning through a combination of academic and work–related activities. WIL programs also provide an opportunity for students to practice or be trained at industry placements (Fig. 7.11). At KMUTT, we aspire to ensure that WIL is an explicit feature of our undergraduate and postgraduate programs, with an emphasis on the student–centered learning.

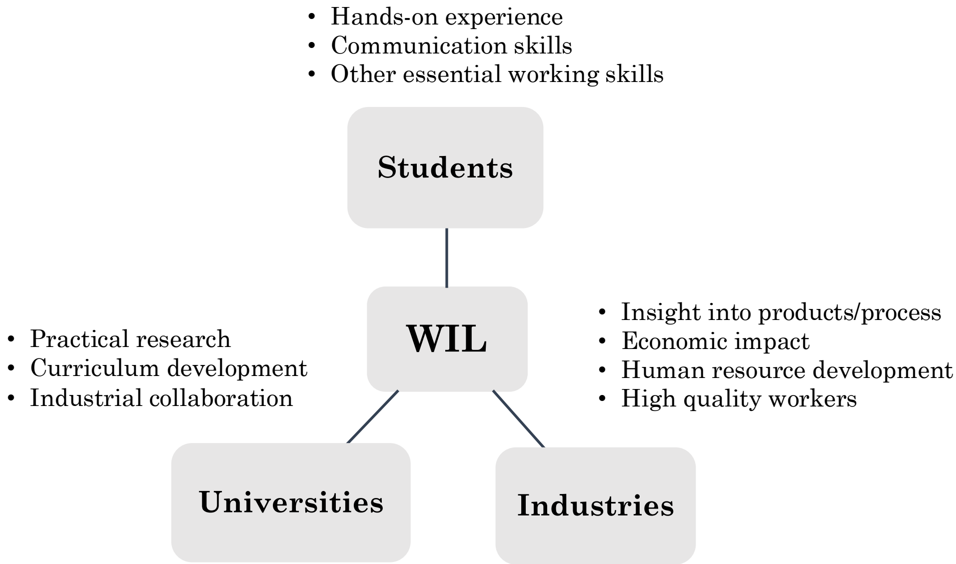

Figure 7.11 Work-integrated learning mechanism

7.6.3.2 Innovation and Technology Assistance Program (ITAP)

ITAP is a technology support program for small and medium enterprises (SMEs) in Thailand, under the National Science and Technology Development Agency through KMUTT's management. The program offers financial support and consultancy services to help SMEs meet the challenges in introducing technology–based products and processes with the assistance of Industrial Technology Advisors, experts, researchers, and students from universities and research institutes (Fig. 7.12).

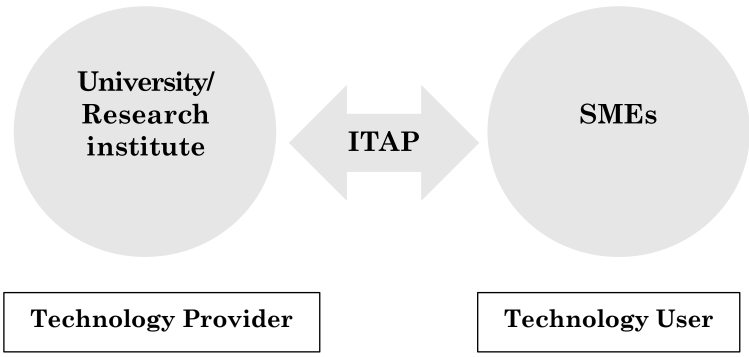

Figure 7.12 Innovation and technology assistance program mechanism

7.6.3.3 Talent Mobility Program (TM)

TM program facilitates the mobility of researchers and students in universities, research organizations, and industries to assist the private sector in technological upgrading for competitiveness and transforming knowledge in the public sector to commercialization in the private sector. This program allows researchers to have vocational education by working full–time and part–time in a different organization for a specific period (3 months to 2 years). This program helps to enhance the skill sets and also provides students an opportunity to enroll as co-researchers (Fig. 7.13).

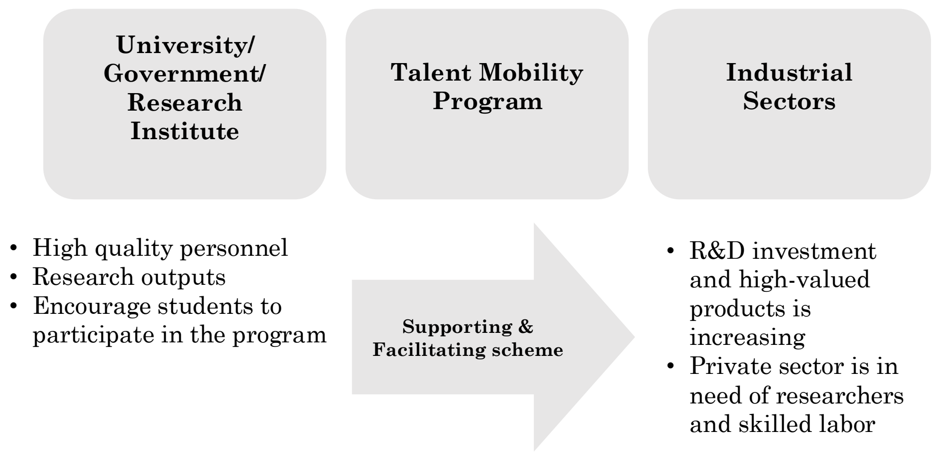

Figure 7.13 Talent mobility mechanism

7.6.3.4 Project–based Learning (PBL)

PBL prepares students for academic, personal, and career success. In this program, students work on a project over an extended period of time that engages them in solving a real–world problem or answering a complex question. Students from SIT, some Japanese universities, and overseas partner universities work together by discussing and solving problems presented by professors, Japanese corporations, and organizations. SIT encourages students to acquire communication skills, problem–solving capabilities, systems thinking, and systems management skills through PBL problem–solving experience (Fig. 7.14).

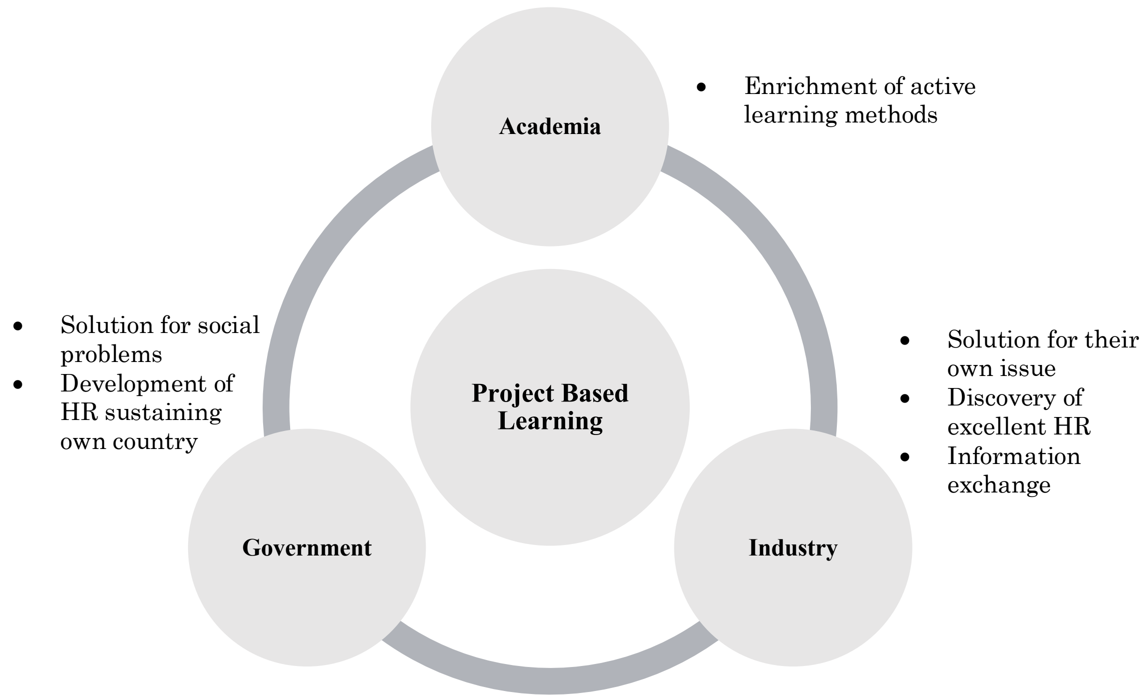

Figure 7.14 Project–based learning mechanism

These programs offer opportunities for students to acquire skill sets and work experience as part of their curriculum and also integrate academic learning with its practical applications in the workplace. These programs can be defined as learning processes obtained through the collaborations between universities and industries.

These programs begin with inquiries from industries to work with researchers and students. The universities provide workforce, resources, and develop a partnership with industries for finding technical solutions and innovations through their various programs.

Meanwhile, the students are assigned to become co-researchers in the team. Figure 7.15 illustrates that students in the group need to communicate with one another using verbal communication skills to clearly articulate the project goals and objectives. Team communication is the foundation of team management that requires some key competencies to achieve mutual recognition and understanding. This competency applies to all types of meetings, presentations, training sessions, and conversations with the industry. Professional communication skills include verbal communication and non–verbal communication complementary to verbal communication. Students also use visual aids such as drawings, diagrams, and symbols to create a PowerPoint presentation to discuss their plans and results to the industry.

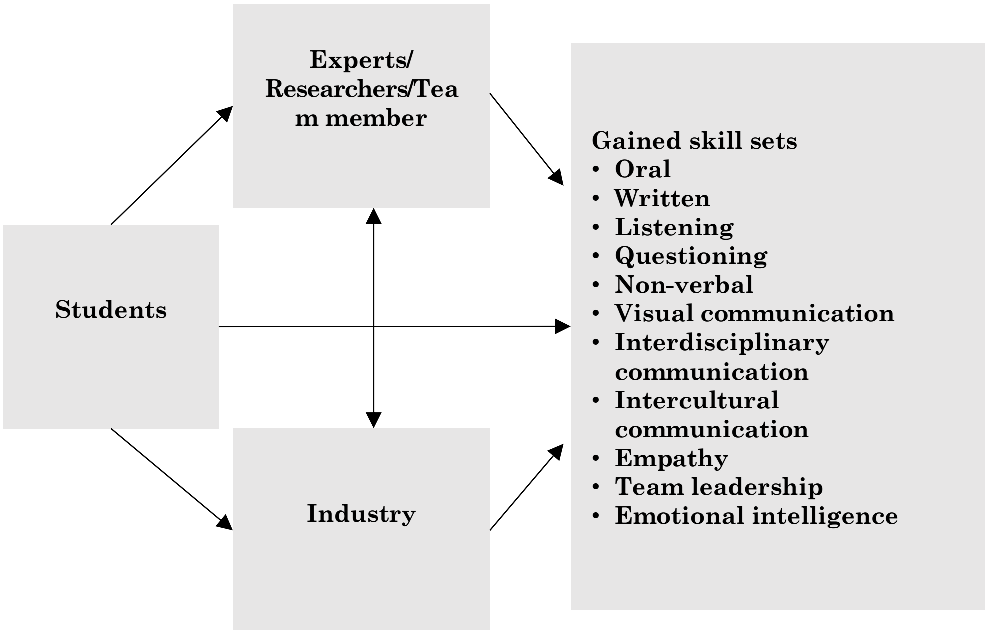

Figure 7.15 Working collaboration and gained competencies

Moreover, programs effective in fostering communication among disciplines are an important aspect that needs to be worked on. Interdisciplinary projects encourage the development of professional communication and team working skills in students. The integration of such projects is partly due to industry needs for engineers who have more expanded skills. Furthermore, EI can enhance the communication skills among team members, utilizing the elements of empathy and social skills.

Each of these programs consists of activities that encourage students to acquire professional communication skills. Table 7.1 summarizes the skill development activities to achieve the goals of the program.

Table 7.1 The development of professional communication skills

Activities	Sample Behaviors	Professional communication developed
First visit (Establishing a relationship)	Greets and make a relationship with other	Oral communication skills, Listening skills, Non-verbal communication skills
	Indicate concern/interest throughout the conversation	
	Use body positioning to indicate interest	
Site visit (gathers information and issues)	Allows the company to complete opening statement without interruption	Listening skills, Questioning skills, Non-verbal communication skills
	Just listen and observe, To absorb all of the information	
	Indicate concern/interest throughout the conversation	
	Make eye contact	
	Use non-judgmental verbalizations	
	Make facilitative responses	
	Use open-ended questions (e.g., What, How, Where, When, Why)	
	Paraphrase or repeat back to achieve greater clarity;	
	- "Sounds like you think…"	
	Deeper fact-finding;	
	- "Could you give me an example?"	
	- "Please tell me more about....?"	
	Summarize; Request feedback;	
	- "Did I get that right?"	
	- "What else do you want to talk about?"	
Project proposal	Developing and using the various elements (e.g., graphic design, drawings, diagrams, and symbolic pictures) in the project proposal	Written communication skills, Visual communication
Working process	Communicate with the company's team to solve the problem	Oral communication skills, Listening skills, Questioning skills, Interdisciplinary
	Brainstorming and discussing with the team member to solve the problem	

	Paraphrase what the team and the company's team are saying. If unclear, ask for clarification. Continue until the others indicate the message was received correctly	communication skills, Intercultural communication skills, Empathy, Team leadership, Emotional intelligence
	While others are talking, Students should not talk or interrupt except to paraphrase after others finished speaking	
Evaluating and concluding the project	Giving a presentation by using body movements including facial expressions, eye contact and voice	Oral communication skills, Presentation skills

First, when the students receive consultancy projects from SMEs, students are assigned to initiate the project to help SMEs solve their issues. Students will join the process called "Site visit" with SMEs to evaluate the nature of the issue at the site (e.g., factory, warehouse, etc.). During their project work, students not only learn problem–solving skills but also develop professional communication skills through teamwork.

The activities help students to develop professional communication skills, viz, oral, listening, and nonverbal communication skills. The behavioral skills impart the capability to ask open–ended questions regarding the problems or challenges in the engineering sector.

Secondly, students, experts, and researchers work together to develop the official project proposal to submit to SMEs and/or submit to funding agencies for approval. Proposal writing is a skill that requires knowledge and practice. Written communication skills of students will be developed by writing the project proposal to submit to funding agencies and the industry for official approval. In addition, visual communication skills, such as drawings, diagrams, graphs, and symbols also can be used in the project proposal to clearly convey ideas and information for better understanding.

Thirdly, experts, researchers, and students perform the problem-solving task. The experts and students jointly work with the industrial team at their site to solve the issue. Last, the project concludes with the submission of the final report by the experts and students, and evaluation of the project outcome by third–party experts nominated by the funding agencies or by SMEs. In this activity, students need to communicate and work with experts, team members, and the industrial staff from various fields. Professional communication skills such as interdisciplinary, intercultural, empathy, and EI skills are developed during this exercise. Meanwhile, leadership and organizational skills are also built.

In the final stage of the project, students are asked to present the results to the industry and funding agencies. Students can improve communication and presentation skills by using body languages such as facial expressions, eye contact, and voice.

It is obvious that these programs enhance the capability of the industry's development team besides solving their particular issue. Moreover, the industrial experts also integrated the issue they encountered into the coursework and curriculum at the university. These programs are beneficial to students for acquiring professional communication skill sets to prepare them for their future careers.

7.7 Conclusion

This research investigated the application of an integrated learning approach known as STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education, as well as offer a STEAM-PBL framework and some instances of engineering programs at two Asian institutions. The following research questions were utilized to achieve this goal:

Research Questions 2: What is the most effective integrated learning approach for achieving professional competency in engineering education?

This research presents a conceptual framework based on learning theories and pedagogies that will lead to the achievement of important learning goals. STEAM project-based learning promotes student skill development by using PBL as an appropriate educational tool to generate a professional experience that strengthens experimental learning and relationships with collaborative partners and the local community, dealing with real and practical life issues, and actual experiences as learning situations.

Student learning were evaluated through observations, one-on-one talks, discussions with project specialists, hand sketches, computer drawings, computation sheets, PowerPoints, models, and replies to open-ended questions. Student progress was visible at each stage of the project, such as at the conclusion, when each group presented a prototype model and a final PowerPoint presentation of their work.

The overview of remarks, as well as individual quotes, presented in this study, are representative of the majority of students and demonstrate how the numerous initiatives provided possibilities for students to become inspired and involved. With design-focused projects, students were empowered through support and ongoing encouragement to identify problems, brainstorm, generate ideas, devise their creative solutions, select choices, and make changes as necessary. While each project was different, student consensus was that they recognized how they were in control of their learning and appreciated having the ability to make their own decisions.

The application of STEAM-PBL in engineering gives a positive impression on students so that learning becomes more meaningful, students have also been able to develop various skills and competencies such as communication, collaboration, problem-solving, systematic thinking, critical thinking, project management, creativity and innovation, analytical thinking, and self-directed learning. The seven-step process identified in this program not only provides students with a systematic process of how to solve a real problem but also provides teachers with various opportunities to assess student learning. By collecting evidence, formally and informally, throughout each step of the engineering design process, teachers were able to assess student reasoning, strategies, procedures, and professional engineering skills. The integration of STEAM-PBL into learning encourages teachers to be able to innovate in organizing creative learning so students can increase learning motivation, provide meaningful learning, and provide opportunities for students to develop their STEAM literacy and professional skills.

However, this study is not suggesting that all domains of integrated STEAM must occur during every STEAM learning experience but STEAM educators should have a strong understanding of the relationship that can be established across domains and by engaging a community of practice.

As highlighted that professional communication skills are essential for engineers who aspire to carry out their professional practice in the global arena and many employers are also seeking professional communication skills in new hires. Thus, universities should play an important role in developing professional communication skills through learning tools with the appropriated model approach, such as STEAM, project-based learning, activities, and professional team-practice apart from providing knowledge and technical skills to engineering students to prepare them for the 21st-century marketplace and sustain in the globalized professional world.

Chapter 8

Conclusion

There are several challenges for the future development of engineering education such as the rapid advances in a range of technology, globalization, the fourth industrial revolution, employability, and sustainability. These challenges will require new types of engineering programs, to help students develop skills in cross-disciplinarily, complexity, and contextual understanding. Future engineering students should be able to understand the needs for technological solutions in context, with sustainable solutions, be able to act in complex situations with the appropriate skills and competencies.

However, engineering education around the world is confronted with the question that how they can improve the engineering education system more effectively and how to prepare engineering students for the jobs of the future?

In summary, future expected graduate outcomes will be delivered by programs that focus on practice, addressing real-world complexity, and integrating the development of technical, professional, and generic competencies to provide authentic learning. Hence, the key strategies for education change were identified as follow;

1) Curriculum contexts and pedagogies will need to change to deliver these requirements. Greater use of open-ended problems and stronger engagement with industry and community is needed. Problem finding, as well as problem-solving, will be required;

2) Engineering programs should emphasize a problem finding/solving and design focus, mathematics and science foundations, and the development of engineering thinking, creativity, and judgment while fostering the capacity for lifelong learning;

3) The engineering education system will need to consider the development of technical and professional skills supporting collaborative, interdisciplinary teamwork, and work outside conventional engineering roles appears likely to be a more important part of engineering education for the future.

Therefore, this dissertation provides the contributions to engineering education with the following strategies for preparing engineering students and education systems fit for the future;

1) Surveys on the needs competencies/skills for an engineering graduate to excel both in the domestic and global labor markets and diversity challenges for preparing engineering students and education systems fit for the future.

2) Surveys on the competency of engineers working at global companies in Thailand to illustrate the gap between the competency expected for engineers by companies and the competency of working engineers measured by PROG test

3) Identify an integrated learning strategy for building professional competency in engineering education to bridge the gap between engineering education and professional practice.

In summary, this dissertation provides the following two contributions;

Research Questions 1: What are the professional engineering competencies that are required to prepare engineering students for their future?

1) The study demonstrated the required abilities/skills for an engineering graduate to thrive in both the local and global labor markets, as well as the required generic competencies for preparing engineering students for professional engineering employment and career success.

The following finding support this contribution:

Research Questions 1a: Is global competency an important consideration for global engineering jobs in multinational companies in Thailand?

Chapter 3: The study investigated the importance of global competencies and skills, provided by Warnick [Warnick, 2010], which required engineering graduates wishing to work globally from the perspective of well-known Thai and multinational companies based in Thailand. As realized that higher education engineering institutions are currently proficient in developing technical competency among engineering graduates, efforts should be made to evaluate current practices and to improve global competency, especially in three following areas:

a) An ability to work in international teams
b) An ability to exhibit a global mindset
c) An ability to speak more than one language including English

Therefore, engineering education systems should aim at improving engineering programs and providing an accurate systems approach to future global engineers. They should also aim at reforming the engineering curriculum to better reflect industry needs by preparing students for multicultural teamwork with the appropriate and essential global skills that will enable graduates to work in multicultural and global environments.

As previously stated in prior studies, GPA and relevant applicable work experience are deemed vital for engineering students in determining whether or not a student meets the requirements and expectations set by the degree program or university. They are, however, not regarded as required qualifications for engineering graduates seeking employment in multinational companies in Thailand and this criterion cannot assess some of the most important components of future success, such as attitude and competency.

This study can be useful to engineering students, university faculties, and engineers with the necessary global competencies to succeed in the workplace and contribute to the wider economic progress of the country.

Research Questions 1b: Is there a mismatch between academic perspectives and engineering industry expectations regarding the importance of global competencies in engineering education?

Chapter 4: The study identified the gaps between academia and engineering industries by investigating the perceptions of higher education institutions when it comes to the importance of global competencies for engineering graduates who aim to work globally and then comparing them with the perspectives of multinational Thai companies in Thailand.

As the respondents in many Thai universities have been efficiently collaborating with the industry sector, therefore, the perspectives of the educational university sector concerning the vital satisfaction competency items tend to be almost the same as the industry sector. The following competency items were confirmed to be the most important competencies for engineers to develop; the ability to work in international teams, the ability to communicate cross-culturally, the ability to exhibit a global mindset, and the ability to speak more than one language including English.

Higher education engineering institutions throughout the world are encouraged to identify opportunities within each course they teach to facilitate the interaction of engineers within a global environment. Efforts to develop global competence among engineering students may include team-based projects, work-focused projects in different countries, the interaction of engineers in a multicultural environment, international educational partnerships among colleges and universities throughout the world, and the use of technology to develop cross-cultural competence through virtual teams. Students' involvement in a global environment throughout their education versus a single study abroad experience will greatly enhance the capabilities of engineering graduates to succeed in a global environment. Based on this study, particular focus should be placed on incorporating each of the required global competencies into the curriculum.

Research Questions 1c: What are the future competencies for three high-skilled jobs in Industry 4.0: robotics engineers, data scientists, and food designers?

Chapter 5: The study identified the future competencies for three demanding careers representative of the high-skilled requirements of Industry 4.0: robotics engineers, data scientists, and food designers and also underlined the significance of the crucial competencies for university graduates to become workforce-ready for the future.

The findings revealed a diverse mix of competencies that are demanded in the current Industry 4.0 environment and will be desired soon. Industry 4.0 focuses predominantly on multidisciplinary tasks. The results of this study indicate that universities and higher education institutions must contemplate ways to inculcate the skill sets in demand within their graduates to prepare the youth for the world of work.

The results revealed that effective communication, active learning, adaptability to change, and leadership should be inculcated in all three groups of graduates aiming to fill the emergent demand for the stated careers. Interestingly, these competencies are expected to form the core abilities for all future personnel.

The upskilling of other capabilities including social, personal, and methodological abilities before youngsters graduate from tertiary educational institutions can also open extensive opportunities for the region's graduates to compete with other, more experienced, candidates. These findings also provide empirical information that can guide relevant faculties and departments that seek to develop future competencies related to these potential jobs in the new digital economy through the establishment of competency-based course curricula.

Research Questions 1d: What are the key generic competencies for preparing engineering students for professional engineering work and career success?

Chapter 6: This study measured the generic competency of Thai working engineers, as the challenge of engineering education is not only to simultaneously prepare students for their first job but they need to prepare them for lifelong learning and career success, by utilizing the Progress Report on Generic Skills (PROG) assessment tool to assess their current generic skill and competency and to analyze the key factors of Thai engineers' competency development in their careers, as well as investigating the key generic competencies for preparing engineering students for professional engineering jobs and career success.

The findings indicate that Thai working engineers in all positions and companies of all sizes scored worse in terms of "Team management skills." Team management refers to a manager's or organization's ability to lead a group of people in completing a task or achieving a common goal. Effective team management is encouraging, interacting with, and supporting team members so that they may perform to the best of their ability and continue to improve as professionals.

Even though there is clear evidence to support the importance of teamwork skills in engineering education, as highlighted from the previous research (Chapter 3) that well-known Thai and Japanese companies rate the ability to work in an international team as an essential competency for engineering students, however, the result reveals that many engineers fall short of meeting these industry requirements and the gap between the industry and academia is still there because Thais place a high value on courtesy and respect for elders and those in positions of power. They are taught to respect superiors, parents, teachers, and the elderly from a young age. Many Thai workers, in particular, have learned not to raise questions. As a result, in Thailand, management style frequently results in employees who do not inquire, question, or confront. It is difficult to elicit their critical thinking and leadership since they do not want to be deemed impolite [Chaidaroon, 2003; Chong, 2008; Malikhao, 2017].

Therefore, to prepare engineering students to be effective in a future workplace, engineering education systems should aim at improving engineering programs and providing an accurate systems approach to future engineers. Engineering programs must contemplate ways to inculcate interdisciplinary teamwork and leadership skills by encouraging them to assert themselves, express their opinion and confidently share their views, and know how to do this respectfully, as increasingly seen as an important component of engineering students for their future work.

Research Questions 2: What is the most effective integrated learning approach for achieving professional competency in engineering education?

2) The study identified an integrative learning approach for fostering professional competency in engineering education.

The following finding support this contribution:

Chapter 7: This study examined the use of an integrative learning approach, which is called STEAM project-based learning (STEAM-PBL) for fostering professional competency in engineering education, and presented a STEAM-PBL framework with three interrelated dimensions: (1) the learning approach, (2) the social approach, and (3) the content approach. The results of this study demonstrated that the application of STEAM-PBL in engineering gives a positive impression on students so that learning becomes more meaningful, students have also been able to develop various skills and competencies such as communication, collaboration, problem-solving, critical thinking, project management, creativity and innovation, systematic thinking, analytical thinking, and self-directed learning. Besides, the integration of STEAM-PBL into learning encourages teachers to be able to innovate in organizing creative learning so students can increase learning motivation, provide meaningful learning, and provide opportunities for students to develop their STEAM literacy and professional skills.

Moreover, some examples of engineering programs from KMUTT and SIT demonstrated that professional skills and competencies of students can be developed through an integrative learning approach which university-industry collaborations model and various pedagogies that have the potential to support the delivery of the T-shaped engineering graduate and the greater breadth of graduate outcomes that will be required in future.

Appendix A

List of Publications

A.1 International journal paper

[J.1] Rawboon, K., Yamazaki, A.K., Klomklieng W. and Thanomsub, W. (2021). Future Competencies for Three Demanding Careers of Industry 4.0: Robotics Engineers, Data Scientists, and Food Designers. Competency-based Education, pp. 1-12, 2021;00:e01253. https://doi.org/10.1002/cbe2.1253

[J.2] Rawboon, K., Yamazaki, A. K., Wongsatanawarid, A., Oda, S. (2021). Global competencies for engineering program graduates from an industry perspective. International Journal of Learning and Teaching, Vol. 7, No. 1, pp. 7-14.

A.2 International conference paper (peer-reviewed)

[C.1] Rawboon, K., Wongsatanawarid, A., Yamazaki, A., & Inoue, M. (2019). Professional Communication Education through Academia-Industry Collaborations: Some Examples at Two Asian Universities. In Proceedings - 2019 IEEE International Professional Communication Conference, ProComm 2019, pp. 178-184.

[C.2] Rawboon, K., Yamazaki, A. K., Oda, S., & Wongsatanawarid, A. (2019). Assessment of global competencies for the development of global engineering education. In ICDTE 2019 - 2019 the 3rd International Conference on Digital Technology in Education, pp. 190-194.

[C.3] Rawboon, K., Yamazaki, A. K., Oda, S., & Wongsatanawarid, A. (2020). Global competencies for engineering education: A comparative study of industry and academic perspectives. In Proceedings of the 5th International Conference on Information and Education Innovations, ICIEI 2020, pp. 66-71.

Bibliography

Abbasi, F. K., Ali, A., & Bibi, N. (2018). Analysis of skill gap for business graduates: Managerial perspective from banking industry. Education and Training, 60(4), 354–367. https://doi.org/10.1108/ET-08-2017- 0120.

Accreditation Board for Engineering and Technology (ABET) (2013). Criteria for accrediting engineering programs: Effective for reviews during the 2014-2015 accreditation cycle. Baltimore, MD: ABET.

Accreditation Board for Engineering and Technology (ABET). Criteria for Accrediting Engineering Programs. Effective for Reviews During the 2017-2018 Accreditation Cycle, 2016, available from http://www.abet.org/wp-con tent/uploads/2016/12/E001-17-18- EAC-Criteria-10-29-16. pdf [Accessed on February 7, 2020].

Accreditation Board for Engineering and Technology (ABET) (2017). Retrieved from www.abet.org. [Consultation: 12th December 2017].

Agrawal, A. K. & Harrington-Hurd, S. (2016). Preparing next generation graduates for a global engineering workforce: Insights from tomorrow's engineers, Journal of Engineering Education Transformations, vol. 29, no. 4, pp. 5-12.

Ahmed, F., Capretz, L. F., Bouktif, S., & Campbell, P. (2012). Soft skills requirements in software development jobs: A cross-cultural empirical study. Journal of Systems and Information Technology, 14(1), 58–81. https://doi.org/10.1108/13287261211221137.

Akman, I., & Turhan, C. (2018). Investigation of employers' performance expectations for new IT graduates in individual and team work settings for software development. Information Technology and People, 31(1), 199–214. https://doi.org/10.1108/ITP-01-2017-0020.

Almi, N. E. A. M., Rahman, N. A., Purusothaman, D. & Sulaiman, S. (2011). Software engineering education: The Gap between Industry's requirements and Graduates' readiness, presented at IEEE Symposium on Computers & Informatics (ISCI), Kuala Lumpur, March 20-23, pp. 542-547.

Aluko, Y. (2014). Employers' perceptions of the employability skills of new graduates in Nigeria. Journal of Educational Review, 7(4), 12.

Anisimova, T., Sabirova, F., & Shatunova, O. (2020). Formation of design and research competencies in future teachers in the framework of STEAM education. Int. J. Emerg. Tech. Learn. (iJET), 15, 204–217.

Asonitou, S. (2015). Employability skills in higher education and the case of Greece. Procedia - Social and Behavioral Sciences, 175, 283–290. https://doi.org/10.1016/j.sbspro.2015.01.1202.

Balliester, T. & Elsheikhi, A. (2018). The future of work: A literature review, ILO Research Department, Working Paper No. 29.

Barrick, M.R., Patton, G.K. & Haugland, S.N. (2000). Accuracy of interviewer judgements of job applicant personality traits, Personnel Psychology, 53, 925–951. https://doi.org/10.1111/j.1744-6570.2000.tb02424.x.

Behn, B. K., Ezzell, W. F., Murphy, L. A., Rayburn, J. D., Stith, M. T., & Strawser, J. R. (2012). The pathways commission on accounting higher education: Charting a national strategy for the next generation of accountants. Issues in Accounting Education, 27(3), 595–600. https://doi.org/10.2308/iace-10300.

Berawi, M. A. (2018). Utilizing Big Data in industry 4.0: Managing competitive advantages and business ethics. International Journal of Technology, 9, 430–433. https://doi.org/10.14716/ijtech.v9i3.1948.

BRICS Business Council (2017). Skill development for Industry 4.0, A White Paper by BRICS Skill Development Working Group, BRICS Business Council, India Group. Online available at http://www.globalskillsummit.com/Whitepaper-Summary.pdf (Accessed on 05.02.2021).

Borrego, M., Karlin, J., McNair, L., & Beddoes, K. (2013). Team Effectiveness Theory from Industrial and Organizational Psychology Applied to Engineering Student Team Projects: A Research Review. Journal of Engineering Education, 102(4), 472-512.

Bourn, D. & Neal, I. (March 2008). The Global Engineer: Incorporating Global Skills within UK Higher Education of Engineers, IOE London, pp. 1–29.

Cicek, K., Akyuz, E., & Celik, M. (2019). Future skills requirements analysis in maritime industry. Procedia Computer Science, 158, 270–274. https://doi.org/10.1016/j.procs.2019.09.051.

Chaidaroon, S. (2003). When shyness is not incompetence: A case of Thai communication competence. In G. M. Chen & Y. Miike (Eds.), Asian approaches to human communication [Special issue]. Intercultural Communication Studies, 12(4), 195-208.

Chong, E. 2008. Managerial competency appraisal: A crosscultural study of American and East Asian managers, Journal of Business Research 61(3): 191-200.

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., and Lee, C. W.Y. (January 2017). Twenty-First century skills and global education roadmaps, in 21st Century Skills Development Through Inquiry-Based Learning, Singapore: Springer.

Colucci-Gray, L., Trowsdale, J., Cooke, C. F., Davies, R., Burnard, P., & Gray, D. S. (2017). Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21st learning: How can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education? British Educational Research Association.

Conlon, E. (2008). The new engineer: Between employability and social responsibility, EJEE, 33, 151-159.

Conrad, D. & Newberry, R. (2011). Business Communication Skills Attitudes of Human Resource Managers versus Business Educators American Communication Journal, 13(1), 4-23.

Cortellazzo, L., Bonesso, S., Gerli, F., & Batista-Foguet, J. M. (2020). Protean career orientation: Behavioral antecedents and employability outcomes. Journal of Vocational Behavior, 116, 103343. https://doi.org/10.1016/j.jvb.2019.103343.

Dalenogare, L.S., Benitez, G.B., Ayala, N.F., & Frank, A.G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383–394. https:// doi.org/10.1016/j.ijpe.2018.08.019.

De Graaff, E., Kolmos, A., (2003). Characteristics of problem-based learning. International Journal of Engineering Education, 19(5), 657-662.

DiBenedetto, C. and Myers, B. May. (2016). A conceptual model for the study of student readiness in the 21st century, NACTA Journal, vol. 60, no. 1a, pp. 28-35.

Dotong, C. I., Chavez, N. H., Pamplona, M. A. I., and Camello, N. C. (2017). Employers' Feedback on Job Performance of Engineering Graduates in one Private Academic Institution in the Philippines.

EL-Sakran, T. and Awad, A. (2012). Voices from the United Arab Emirates: Engineering graduates' Labour market requisite competencies, American Journal of Engineering Education, vol. 3, no. 2, pp. 105-114.

Engineers Australia. (2019). Engineering in Complex, Interdisciplinary Projects – Latest Insights. Online available at https://www.engineersaustralia.org.au/event/2019/06/engineering-complex-interdisciplinary-projects-latest-insights (Accessed on 05.03.2021).

Esparragoza, I., Ocampo, J., Rodriguez, J., Lascano, S., Ivashyn, U., Sacchelli, C., Vigano R., & Duque J. (2016). Engineering student motivation on multinational projects: A comparison based on interest, value and gender, in Proc. 14th LACCEI International Multi-Conference for Engineering, Education and Technology.

European Commission (2017). Key lessons from national industry 4.0 policy initiatives in Europe.

European Network for Accreditation of Engineering Education - EUR-ACE® Framework Standards and Guidelines. (2015). [Consultation: 3rd December 2017].

Fantini, A. E., Arias-Galicia, F., and Guay, D. (2001). Globalization and 21st Century Competencies: Challenges for North American Higher Education, Boulder, CO: Western Interstate Commission for Higher Education.

Fareri, S., Fantoni, G., Chiarello, F., Coli, E., & Binda, A. (2020). Estimating Industry 4.0 impact on job profiles and skills using text mining. Computers in Industry, 118, 103222. https://doi.org/10.1016/j.compind.2020.103222.

Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. Journal of Engineering Education, 92(1), 7-25. https://doi.org/10.1002/j.2168-9830.2003.tb00734.x

Ferrari, A. (2013). DIGCOMP: A framework for developing and understanding digital competence in Europe. Publications Office of the European Union, Luxembourg.

Finch, D. J., Hamilton, L. K., Baldwin, R., & Zehner, M. (2013). An exploratory study of factors affecting undergraduate employability. Education and Training, 55(7), 681–704. https://doi.org/10.1108/ET-07-2012-0077.

Fitsilis, P., Tsoutsa, P., & Gerogiannis, V. (2018). Industry 4.0: Required personnel competences. Industry 4.0, 3(3), 130-133.

Gray, E. (2010). Specific oral communication skills desired in new accountancy graduates. Business Communication Quarterly, 73(1), 40–67.

Hadgraft, R. & Kolmos, A. (2020). Emerging Learning Environments in Engineering Education. Australasian Journal of Engineering Education, 25(3), 1-14. DOI: 10.1080/22054952.2020.1713522

Halliday, J. (2000). Critical thinking and the academic vocational divide. The Curriculum Journal, 11(2), 159–175. http://dx.doi.org/10.1080/09585170050045182

Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. Procedia CIRP, 54(1), 1–6.

Hernández-March J., Martín del Peso M., & Leguey S. (2009). Graduates’ skills and higher education: The employers’ perspective. Tertiary Education and Management, 15, 1, 1–16.

Hetland, L., & Winner, E. (2004). Cognitive transfer from arts education to non-arts outcomes: Research evidence and policy implications. In E. W. Eisner, & M. D. Day (Eds.). Handbook of research and policy in art education, pp. 135–162.

Hinton, S. (2018). How The Fourth Industrial Revolution Is Impacting The Future of Work, Forbes, available online at https://www.forbes.com/sites/theyec/2018/10/19/how-the-fourth-industrial-revolution-is-impacting-the-future-of-work/?sh=37d34fd965a7. (Accessed on 05.02.2021).

Hollister, J. M., Spears, L. I., Mardis, M. A., Lee, J., McClure, C. R., & Liebman, E. (2017). Employers’ perspectives on new information technology technicians’ employability in North Florida. Education and Training, 59(9), 929–945. https://doi.org/10.1108/ET-02-2017-0019.

Hong Kong Institution of Engineers. (2013). Professional accreditation handbook (Engineering degrees).

https://www.hkie.org.hk/zhhant/quali/criteria/upload/page/55/self/59ba2b4d548ec.pdf

Industrial Technology Research Institute (ITRI) (2019). 2030 Advanced Technology from an Asian Perspective. Online available at https://ieeecs-media.computer.org/media/tech-news/2030-advanced-tech-asia-perspective-itri.pdf (Accessed on 12.02.2021).

Jameson, A., Carthy, A., McGuinness, C., & McSweeney, F. (2016). Emotional intelligence and graduates–Employers' perspectives. Procedia - Social and Behavioral Sciences, 228(June), 515–522. https://doi.org/10.1016/j.sbspro.2016.07.079.

Jonassen, D. (2011). Supporting problem solving in PBL. Interdisciplinary Journal of Problem-based Learning, 5(2), 8. https://doi.org/10.7771/1541-5015.1256

Jones, C., & Pimdee, P. (2017). Innovative ideas: Thailand 4.0 and the fourth industrial revolution. Asian International Journal of Social Sciences, 17(1), 4–35. https://doi.org/10.29139/aijss.20170101.

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for Implementing the Strategic Initiative Industrie 4.0: Securing the Future of German Manufacturing Industry. Final Report of the Industrie 4.0 Working Group. Acatech, Forschungsunion.

Katarzyna G., & Anna Ł. (2017). Key competencies for Industry 4.0. Economics & Management Innovations, 1(1), 250–253.

Keen, M., Brown, V., Dyball, R. (Eds.). (2005). Social Learning in Environmental Management: Towards a Sustainable Future. Earthscan, London.

Kergroach, S. (2017). Industry 4.0: New challenges and opportunities for the labour market. Foresight and STI Governance, 11(4), 6–8. https://doi.org/10.17323/2500-2597.2017.4.6.8.

Kinnunen, T., & Parviainen, J. (2016). Feeling the right personality. Recruitment Consultants'affective decision making in interviews with employee candidates. Nordic Journal of Working Life Studies, 6(3), 5. https://doi.org/10.19154/njwls.v6i3.5525.

Kolmos, A., & De Graaff, E. (2014). Problem-Based and Project-Based Learning in Engineering Education: Merging Models, Cambridge Handbook of Engineering Education Research, 141-160.

Koppi T., Sheard J., Naghdy F., Chicharo J., Edwards S. L., Brookes W., & Wilson D. (2009). What our ICT graduates really need from us: A perspective from the workplace. In Proceedings of the eleventh Australasian conference on computing education, Wellington: Australian Computer Society, Inc, 95, 101–110.

Krueger, R.A, & Casey, M.A. (2000). Focus Groups:A Practical Guide for Applied Research. 3rd ed. Thousand Oaks, CA: Sage

Levonisova, S. V. et al. (2015). Identifying factors that enhance undergraduate engineering students' global preparedness, presented at the 2015 ASEE Annual Conference and Exposition, Seattle, WA.

Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: implications for SCM. Supply Chain Management: An International Journal, 24,124–146.

Li, L. (2018). China's manufacturing locus in 2025: with a comparison of "Made-in-China 2025" and "Industry 4.0." Technological Forecasting and Social Change, 135, 66-74. https://doi.org/10.1016/j.techfore.2017.05.028.

Lingard, R. & Barkataki, S. (October 2011). Teaching teamwork in engineering and computer science, presented at the 41st ASEE/IEEE Frontiers Edu. Conf., Rapid City, SD, USA.

Liu, Z., & Schonwetter, D. J. (2004). Teaching creativity in engineering. International Journal of Engineering Education, 20(5), 801–808.

Male, S. A. (2010). Generic engineering competencies: A review and modelling approach," Education Research and Perspectives, vol. 37, no. 1, pp. 25-51.

Male, S.A., Bush, M.B., & Chapman, E.S. (2010). Perceptions of Competency Deficiencies in Engineering Graduates. Australasian Journal of Engineering Education, 16(1), 55-67.

Male, S.A., Bush, M.B., & Chapman, E.S. (2011). Understanding Generic Engineering Competencies. Australasian Journal of Engineering Education, 17(3), 147-156.

Malikhao, P. (2017). Culture and communication in Thailand. Singapore: Springer.

Martin, R., Maytham, B., Case, J. and Fraser, D. (2005). Engineering Graduates' Perceptions of How Well They Were Prepared for Work in Industry. European Journal of Engineering Education, 30, 2, 167-180.

Matsumura, N. & Tanabe, A. (2019). The Development of PROG, and Performance Assessment of International PBL with PROG, JSEE Annual Conference International Session Proceedings, Japanese Society for Engineering Education, September 5-6.

Miao, C., Humphrey, R. H., & Qian, S. (2017). A meta-analysis of emotional intelligence and work attitudes. Journal of Occupational and Organizational Psychology, 90(2), 177–202. https://doi.org/10.1111/joop.12167.

Mohammad S., Nor, H. Md., Omar, W. & Mohamed, D. (2004). Enhancing teaching and learning through the incorporation of generic skills for civil engineering undergraduates," in Proc. Conference on Engineering Education (CEE 2004), Kuala Lumpur.

Morell, L. & Trucco, M. (2012). A proven model to re-engineer engineering education in partnership with industry, in World Engineering Education Forum, Buenos Aires, Argentina.

Morreale, S. P., & Pearson, J. C. (2008). Why communication education is important: The centrality of the discipline in the 21st century. Communication Education, 57(2), 224–240. https://doi.org/10.1080/03634520701861713.

Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S. (2017). How will change the future engineers' skills in the Industry 4.0 framework? A ouestionnaire survey. Procedia Manufacturing, 11, 1501–1509. https://doi.org/10.1016/j.promfg.2017.07.282.

National Academy of Engineering. (2004). The Engineer of 2020:Visions of Engineering in the New Century, National Academies Press.

Nicolescu, L. & Paun C. (2009). Relating higher education with the labour market: Graduates' expectations and employers' requirements. Tertiary Education and Management, 15, 17–33.

Oda, S., Yamazaki, A. K. and Inoue, M. (2018). Review of previous research and Japan-US comparative study of global competency in Engineering, JAGCE, vol. 6, no. 1.

Office of National Higher Education Science Research and Innovation Policy Council (NXPO) (2020). Results of skill mapping in the twelve new S-curve industries. Available at https://www.nxpo.or.th/th/en/report/5608/.

Pandey, A. and Chairungruang, S. (2020). Effects of Organizational Support, Supervisor Support and Coworkers' Interpersonal Helping Behavior on Employee Job Satisfaction: A case study in Bangkok, Thailand. International Journal of Economics, Business and Accounting Research, Vol. 4, No. 2, pp. 1-11.

Paretti, M. C., Cross, K. J., & Matusovich, H. M. (2014). Match or Mismatch: Engineering Faculty Beliefs about Communication and Teamwork versus Published Criteria. Presented at the American Society for Engineering Education Annual Conference, Indianapolis, IN.

Parkinson, A. (2009). The rationale for developing global competence, Online J. Glob. Eng. Educ., vol. 4, no. 2, September 2009.

Passow, H. J. (2012). Which ABET competencies do engineering graduates find most important in their work? Journal of Engineering Education, 101(1), 95–118. http://dx.doi. org/10.1002/j.2168-9830.2012.tb00043.x

Perignat, E. & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity, 31, 31-43. https://doi.org/10.1016/j.tsc.2018.10.002

Pinzone, M., Fantini, P., Perini, S., Garavaglia, S., Taisch, M., & Miragliotta, G. (2017). Jobs and skills in industry 4.0: An exploratory research. IFIP Advances in Information and Communication Technology, 513, 282–288. https://doi.org/10.1007/978-3-319-66923-6_33.

Polukhina, M., and Doskovskaya, M. (2018). Higher education and global competence: Renewing the educational concept of universities in Russia. Proceedings of the International Scientific Conference. Rezekne: Open Journal Systems. 444-453. DOI= http://dx.doi.org/10.17770/sie2018vol1.3113.

Popkova, E. G., & Zmiyak, K. V. (2019). Priorities of training of digital personnel for industry 4. 0: Social competencies vs technical competencies, 27(3), 138–144. https://doi.org/10.1108/OTH-08-2019-0058.

Psycharis, S. (2018). STEAM in education: A literature review on the role of computational thinking, engineering epistemology and computational science. Computational STEAM pedagogy (CSP). Scientific Culture, 4(2), 51–72.

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. School Science and Mathematics, 117(1-2), 1–12.

Rahmat, A. M., Adnan, A. H. M., & Mohtar, N. M. (2019). Industry 4.0 skillsets and "career readiness": Can Malaysian university students face the future of work? In Proceedings of the International Invention, Innovative & Creative (InIIC) Conference, Series, 978–967.

Rahmat, A. M., Adnan, A. H. M., & Mohtar, N. M. (2020). Becoming Industry 4.0 workers: Technical, methodological, social, personal and digital processing capabilities. In N. F. Habidin et al. (eds.), The Management of Work Performance, Safety and Entrepreneurship Trend in Malaysia, 103–111.

Rawboon, K., Oda, S., Yamazaki, A.K., and Wongsatanawarid, A. (2019a). Assessment of global competencies for the development of global engineering education. In Proceedings of the 2019 the 3rd international conference on digital technology in education. 190-194. DOI= https://doi.org/10.1145/3369199.3369244.

Rawboon, K., Yamazaki, A. K., Wongsatanawarid, A., Oda, S. (2021). Global competencies for engineering program graduates from an industry perspective. International Journal of Learning and Teaching, Vol. 7, No. 1, pp. 7-14. DOI: 10.18178/ijlt.7.1.7-14

Rawboon, K., Wongsatanawarid, A., Yamazaki, A.K., and Inoue, M. (2019b). Professional communication education through academia-industry collaborations: some examples at two Asian universities. In Proceedings of the 2019 IEEE International Professional Communication Conference. 178-184. DOI= 10.1109/ProComm.2019.00038.

Root-Bernstein, R. (2015). Arts and crafts as adjuncts to STEM education to foster creativity in gifted and talented students. Asia Pacific Education Review, 16(2), 203–212.

Saniuk, A., Saniuk, S., Caganova, D., & Cambal, M. (2014). Control of strategy realization in metallurgical production. In 23rd International Conference on Metallurgy and Materials Location: Brno, CZECH REPUBLIC, 1876–1881.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. Hmelo-Silver, and P. A. Ertmer (eds), Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, pp 5- 15. West Lafayette, Indiana: Perdue University Press.

Scott, G., & Yates, K. W. (2002). Using successful graduates to improve the quality of undergraduate engineering programmes. European Journal of Engineering Education, 27(4), 363–378. http://dx.doi.org/10.1080/03043790210166666

Shatunova O., Anisimova T., Sabirova F. & Kalimullina O. (2019). STEAM as an Innovative Educational Technology. Journal of Social Studies Education Research, 10(2), 131-144.

Shuman, L. J., Besterfield-Sacre, M. & McGourty, J. (2005). The ABET 'Professional Skills' - Can they be taught? Can they be assessed?, J. of Eng. Educ., vol. 94, no. 1, pp. 41-55, January 2005.

Spinks, N., Silburn, N., & Birchall, D. (2006). Educating engineers for the 21st century: The industry view. Henley-on-Thames, UK: Henley Management College.

Spooren, P., Mortelmans, D., & Denekens, J. (2007). Student evaluation of teaching quality in higher education. Development of an instrument based on 10 Likert scales. Assessment and Evaluation in Higher Education, 32, 667–679. https://doi.org/10.1080/02602930601117191.

Streiner, S. C., Vila-Parrish, A. R. and Warnick, G. M. (April 2015). An exploratory study of global competencies considered by multinational companies: A hiring perspective, Int. J. Eng. Educ., vol. 31, no. 5, pp. 1239–1254.

Suleman, F., & Laranjeiro, A. M. C. (2018). The employability skills of graduates and employers' options in Portugal. Education + Training, 60(9), 1097–1111. https://doi.org/10.1108/et-10-2017-0158.

Supjarerndee, S., Temtanapat, Y., & Phalavonk, U. (2002). Recruitment filtering with personality-job fit model. Proceedings - International Conference on Information Technology: Coding and Computing, ITCC 2002, 14(3), 46–51. https://doi.org/10.1109/ITCC.2002.1000358.

The National Reform Council (2016). Blue Print and Action Plan for the Drive of Thailand 4.0. Model Drive of Thailand towards Stability, Wealth and Sustainable. Bangkok: Printed material.

Thoben, K.D., Wiesner, S., & Wuest, T. (2017). Industrie 4.0 and smart manufacturing–A review of research issues and application examples. International Journal of Automation Technology, 11(1), 4-16. https://doi.org/10.20965/ijat.2017.p0004.

Thomas, I. (2009). Critical thinking, transformative learning, sustainable education, and problem-based learning in universities. Journal of Transformative Education, 7(3), 245-264. https://doi.org/10.1177/1541344610385753

Uhlenbrook, S. & Jong, E. D. (2012). T-shaped competency profile for water professionals of the future, Hydrology and Earth System Sciences Discussions, 9(3), 2935-2957.

UNESCO. (2015). Rethinking Education: Towards a Global Common Good? UNESCO, Paris.

UNESCO. (2017). Sustainable Development Goals. Retrieved from http://en.unesco.org/sdgs

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2019). Determinants of 21st-century digital skills: A large scale survey among working professionals, Computers in Human Behavior, 100, 93-104. https://doi.org/10.1016/j.chb.2019.06.017

Virtanen, A. & Tynjälä, P. (2018). Factors explaining the learning of generic skills: a study of university students' experiences. Teaching in Higher Education DOI: 10.1080/13562517.2018.1515195.

Warnick, G. M. (2010). Global competence: Determination of its importance for engineers working in a global environment, dissertation, University of Nebraska–Lincoln, Lincoln, NE.

Warnick, G. M. (2011). Global competence: Its importance for engineers working in a global environment," presented at the 118th Annual Conference and Exposition, Vancouver, British Columbia, Paper Number 2011-350.

Wellington, P., Thomas, I., Powell, I., & Clarke, B. (2002). Authentic assessment applied to engineering and business undergraduate consulting teams. Inter. J. of Eng. Educ., 18, 2, 168-179.

Wolf, M. (2014). Shaping Globalization, Finance & Development, 51(3), 22-25.

Woods, DR., Briedis, D. and Perna, A. (2013). Professional skills needed by our graduates. Chem. Eng. Ed. 47, 81-90.

World Economic Forum (WEF) (2018). The Future of Jobs Report 2018, Centre for the New Economy and Society, Geneva, Switzerland.

World Economic Forum (WEF) (2020), The future of Jobs Report 2020. Available at https://www.weforum.org/reports/the-future-of-jobs-report-2020.

Xu, L.D., Xu, E.L., & Li, L. (2018). Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806.