Global Competencies for Engineering Program Graduates from an Industry Perspective

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***Abstract*—Twenty-first century education in engineering has expanded from a local to a global level. Nowadays, it plays a significant role in connecting students with the global community and raising awareness of global issues. 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 in recent years. It is crucial that engineering graduates' competencies and skills match the features and qualities required by the industry. The purpose of this study is 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. It is anticipated that the findings of this research work will be useful to engineering students, faculties, and management teams of institutes in developing a new engineering curriculum that provides the necessary competencies and skills. In this way, it will also be useful to industry by providing professional engineers with the appropriate global competencies and skills, thus contributing to the economic progress of the country.**

***Index Terms*—global competency, the twenty-first century, engineering education, engineering student, multinational company, industry perspective**

I. Introduction

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 [1]–[4]. Global competency has been increasingly acknowledged as an essential prerequisite for newly graduated engineering students preparing to join multinational companies [5], [6]. It is also regarded as a core skill that all students must acquire [1]. 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 [7] 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 [8]. 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 is 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. 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.

The results of this study are expected to help engineering departments at universities in Thailand, Japan, and other countries enhance their current engineering curriculum.

II. Literature Review

A. 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.

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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 [9]. 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 [10]. 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 [11]. Therefore, the participation of industry professionals in engineering education must be an integral part of the engineering curriculum.

B. 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 [12] 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 [13] 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 [14]. The industry also seeks graduates, who can collaborate within a diverse culture workforce, and who possess in-depth expertise within a single domain [15].

However, recent research has revealed that the skills and competencies of university graduates are not aligned with the needs of the industry sectors [16]–[18]. There is a wide gap between industry requirements and graduates' ability to meet these requirements [19]. 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 [20] 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 [21] 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.

III. METHODOLOGY

The purpose of this study is 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 in Thailand. There is a lack of research from an industry perspective on how multinational companies view global competencies in relation 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 I, we identified 15 competencies. These include eight global competencies and five technical engineering competencies. For comparison, GPA and work experience were also included.

TABLE I. 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 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).

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.

IV. 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 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 II.

TABLE II. 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 degree. 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 III.

TABLE III. 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

TABLE IV. 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 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 IV.

The survey respondents also provided their job title. 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 V,

TABLE V. 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 VI.

TABLE VI. Industry Types of 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 VII, the majority (61%) of the respondents worked in Thai companies,

22% worked in Japanese companies, and 17% worked in other multinational companies.

TABLE VII. 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

TABLE VIII. 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

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 VIII.

Finally, the respondents were asked to evaluate 15 competence items, 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 IX.

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 IX, 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.

TABLE IX. 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

In Table IX, 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.

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.

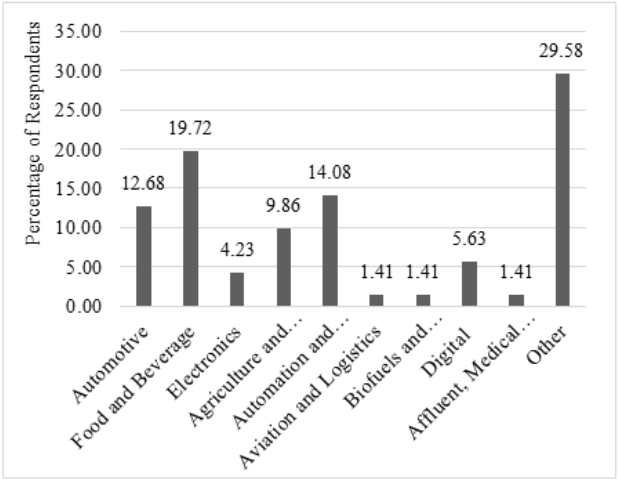

Figure 1. Industry type of well-known Thai companies.

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 Figs. 1–2, 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 [22].

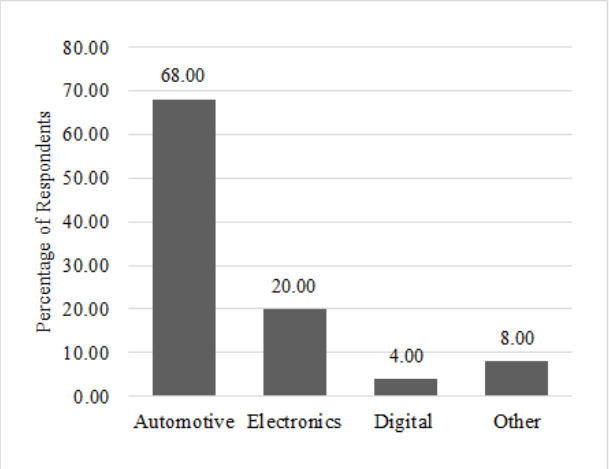

Figure 2. Industry type of Japanese companies.

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 [23], [24]. 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.

V. 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. 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.

In addition to teaching technical skills, engineering programs should prepare 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.

Conflict of Interest

The authors declare no conflict of interest.

Authors Contributions

Khwanruethai conducted the research and analyzed the data; all authors discussed the results and wrote the paper; all authors approved the final version.

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