DEVELOPING A SELF-ASSESSMENT TOOL FOR ENGINEERING STUDENTS: THE SELF-EFFICACY INVENTORY FOR PROFESSIONAL ENGINEERING COMPETENCY (SEIPEC)

by

Xinrui Xu

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THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Joyce Main, Chair

School of Engineering Education

Dr. Michael Loui

School of Engineering Education

Dr. Allison Godwin

School of Engineering Education

Dr. Beth Elmore

University Innovation Alliance – Purdue Center for Career Opportunities

Approved by:

Dr. Donna Riley

Head of the Graduate Program

To my parents, who believe that girls deserve to get a good education as much as boys.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Author: Xu, Xinrui, PhD
Institution: Purdue University
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Title: Developing A Self-Assessment Tool for Engineering Students: The Self-Efficacy Inventory for Professional Engineering Competency (SEIPEC)
Committee Chair: Joyce Main

Although ABET has outlined educational outcomes to help prepare students with the necessary competencies to succeed in professional engineering practice, it is unclear how confident students are in their professional engineering skills. *Competency* refers to the *"generic, integrated and internalized capability to deliver sustainable effective performance in a certain professional domain, job, role, organizational context, and task situation."* Understanding their competency provides students with a bridge to connect their academic experiences with their ability to perform their workplace duties. To help students assess their competency, I developed the Self-efficacy Inventory for Professional Engineering Competency (SEIPEC), an inventory that aims to measure engineering students' self-efficacy for professional engineering competencies. Unlike other inventories in engineering that measure the academic experience or other self-efficacy inventories that do not focus on the engineering population, this career assessment is designed for college-level engineering students to evaluate their subjective readiness for successful performance in the workplace.

SEIPEC is a tool for students to self-assess their professional competencies, aiming to empower students to become reflective about their learning and increase awareness of workplace competencies. SEIPEC was developed based on the American Association of Engineering Societies' Engineering Competency Model (ECM). The ECM identifies factors that contribute to self-efficacy for professional engineering competency. ECM was developed using the Delphi method and encompasses a comprehensive list of competency statements that were approved by industry leaders and engineering educators to encapsulate the competencies needed for a professional engineer.

The data include 434 complete responses from bachelor's and master's students at a Midwest research-intensive university. The sample represents 13 engineering disciplines, such as electrical and computer engineering and mechanical engineering, and includes 282 male and 146

female students, 48 first-generation students, and 63 international students. After the exploratory factor analysis and the confirmatory factor analysis, a four-factor model with 20 competency statements was validated as the measurement for self-efficacy for professional engineering competency. The four factors that contribute to the self-efficacy of professional engineering competency include (a) sustainability and societal impact, (b) health and safety, (c) application of tools and technologies, and (d) engineering economics.

The SEIPEC tool has the potential to empower engineering students to reflect upon and connect their academic experience with professional competencies. SEIPEC would provide students with a method to self-evaluate their skills in addition to other assessment methods such as course grades and traditional engineering exams. The results of self-assessment for professional engineering competencies could increase students' awareness of professional competencies, thus helping students to become more intentional in connecting learning with their professional preparation. Career advisors and counselors can also use this tool to guide career advising conversations revolving around students' choice to pursue and prepare for engineering as a career path.

POSITIONALITY STATEMENT

Trained as an electrical engineer for my undergraduate study, I always doubted that engineering was a suitable career path for me. I had to work very hard for mediocre grades in my math and physics classes; during many evenings and weekends in my junior year, I had a hard time figuring out what went wrong with my C++ code and felt really frustrated. Following my instincts, I tested out counseling in my master's study and fell in love with the discipline and profession. Trying to make the most of both my engineering and counseling training, I started my journey as a graduate student in the School of Engineering Education while working as a career counselor at Purdue University. As a career counselor, every now and then I met with an engineering student like me who was losing confidence in their ability to master the course materials, which left them feeling confused about a future career choice.

In my work as a career counselor, I see a lot of self-doubt among engineering students trying to decide whether to leave or stay. Sometimes when a student contemplates leaving it might not be due to lack of interest in the subject, but rather lack of confidence in their ability to persist and succeed in their chosen path. A desire to help these students to make more informed decisions about their career choices motivated me to explore solutions and tools to guide students toward a better understanding of themselves and engineering careers. I wondered how students perceived their confidence in the competencies required for professional engineers.

Career assessment tools (e.g., Strong Interest Inventory) are widely used in career counseling settings to help students to identify their interests and motivation (Shivy & Koehly, 2002). Based on John Holland's (1976) typology theory, the Strong Interest Inventory helps students to identify their interest area and provides further insight regarding career choices (Donnay & Borgen, 1996). However, the tool was not designed for engineers only, so often students receive "engineering" as an occupational interest with no further information about the various career paths within engineering. This could be helpful for students who are contemplating a variety of choices, but not for engineering students who are debating whether to leave or stay while struggling to achieve high grades in their engineering courses.

In this dissertation work, I am taking a first step in exploring ways to help students better assess their fit with professional engineering work. The process of developing a self-efficacy inventory for professional engineering competencies was very challenging but rewarding. The results of my work helped me to gain a deeper insight into students' understanding of professional engineering competencies. In future work I will continue to seek to improve the inventory, and hope to convert it into a useful career assessment tool.

INTRODUCTION

Need for a Competent Engineering Workforce

With the development of technology and its wide application in all sectors of work, the categories of jobs that require STEM skills and knowledge are expanding (Olson & Riodan, 2012; Augustine, 2005). Also, the number of STEM workers in the labor force has been growing steadily; a Bureau of Labor Statistics projection in 2015 suggested that “the architectural, engineering, and related services industry is projected to grow by 8.0 percent from 2014 to 2024” (Fayer, Lacey, & Watson, 2017). Although the need for more STEM workers varies from segment to segment in the job market, the job market relies on more STEM workers to perform jobs in the era of the technology-driven economy (Xue & Larson, 2015). Among all STEM occupations, computer positions and engineers had the largest projected job openings between 2014 and 2024; the architectural, engineering, and related services industry was projected to be the largest growing industry among the STEM occupations (Fayer et al., 2017).

In the report entitled *The Engineer of 2020,* the vision is that in the future engineers will take on responsibilities beyond technological innovation, seeking also to use engineering to solve the world’s most complex and changing challenges (NAE, 2004). Engineers are expected to become a positive influence on public policy, making wise and economically sustainable decisions for the world. According to the industry leaders from the *Transforming Undergraduate Education in Engineering* (2013) report, in addition to a strong foundation in math and science, which has always been expected from engineers, future engineers are also expected to possess skills in programming and systems thinking, and the ability to use relevant tools as foundational competencies. Beyond engineering foundations, many more general skills are expected for future engineers, including “good communication skills, persistence, curious learning capability, drive and motivation, economics and business acumen, high ethical standards, critical thinking, and willingness to take calculated risks.” (TUEE, 2013, p. 2)

Preparation for the Workforce

Preparing engineering students to join the workforce is critical to responding to the need for a competent engineering workforce (Passow & Passow, 2017; Augustine. 2005). Education institutions need to invest in efforts to bridge the gap between academic learning and employment. First, such efforts would increase the employability of engineering graduates and prepare them for a successful transition from school to work. Second, competent, well-trained engineers would address the call of the workforce and contribute to the welfare of society. Preparing students for employment is crucial for higher education because the value of higher education has been questioned. College education could be expensive, but graduates with a college degree might not be completely career-ready (Grant, 1979; Passow & Passow, 2017). Although preparing graduates for the workforce is not the sole purpose of a college degree, this is an integrated part of the mission of higher education (ABET, 2019; NAE, 2004). In the ecosystem of post-secondary education in the United States, in addition to the academic departments, career services have played an important role in bridging the gap between education and employment by connecting students with employers and providing career education for students to effectively secure internships and job opportunities (Dey & Cruzvergara, 2014).

Getting students career-ready is not just the goal of the educational community and employers, but also a main concern of students. Many students who choose engineering were attracted to this career path due to promising career outcomes (Lent, Brown, Schmidt, Brenner, Lyons, & Treistman, 2003). Besides schoolwork and other common academic efforts, students also participate in experiential learning opportunities such as internships, cooperative education, and research to prepare themselves to join the workforce (Renganathan, Ambri Bin Abdul Karim, & Li, 2012). These experiences allow students not only to apply learned materials to real-world problems but also to develop transferrable skills, which are the basic competencies desired by employers across many job sectors.

Competency

The term competency is widely used in the research and practice of human resources management, as well as higher education. Generally, competency refers to criterion-based, outcome-oriented clusters of descriptions of knowledge, skills, and abilities that will allow an individual to successfully perform designated tasks (McClelland, 1973). Professional competencies play an important role in defining and assessing students' educational outcomes, which impacts their level of readiness to secure a job after graduation. Because competency is a criterion-based concept, many professional associations related to education and employment propose their own expected competencies. The engineering accreditation agency ABET has proposed seven categories of desired competencies for engineering programs to use as a guideline when developing the curriculum. Besides accreditation agencies and higher education institutions, employers also care about students' competency development. The National Association for College and Employer (NACE) proposed an eight-competency framework that illustrates professional competencies, which are competencies that employers look for in their best candidates (NACE, 2017).

Competency-based education emphasizes the student learning outcome compared to the traditional curriculum-centered approach (Barrick, 2017). In competency-based learning the expected outcomes are clearly defined, and students are given flexibility in the pace at which they achieve the goals. The theory and practice of competency-based education provides students with autonomy in the learning process. This autonomy motivates students to own the learning process.

Assessing Competencies

Assessment has been an important component in competency-based learning and education. In competency-based learning, assessment strategies come in various forms, including traditional quizzes and exams, 360-degree assessments, behavioral assessments, portfolios, and more (Henri, Johnson, & Nepal, 2017). Among the many assessment strategies, self-assessment (e.g., portfolio, 360-degree assessment) requires students to reflect on their experiences and generate an evaluation of their own work. The successful adoption of self-assessment in students' outcome assessment depends on students' accurate understanding of their own abilities (Falchikov & Boud, 1989). In order to address the limitations of self-assessment due to inaccurate self-understanding, I am using the concept of self-efficacy, which captures students' confidence in their ability other than their perception of their actual abilities.

Self-efficacy is a powerful and well-tested psychological construct that captures a person's confidence in completing certain tasks (Bandura, 1977). Self-efficacy has been used as a robust measure in much educational research to assess students' confidence with regard to their learning experiences and educational choices (e.g., Miller et al., 2015). Also, self-efficacy is an important construct in career development and decision-making processes, predicting outcome expectations, interests, goals, choices, and performance (Lent, Lopez, Lopez, & Sheu, 2008). Self-efficacy is found to be associated with students' interests and career choices in that when students have high self-efficacy towards tasks associated with studying a discipline, it is likely that they develop strong interests and choose their major accordingly (Lent et al., 2008). Measuring students' self-efficacy regarding engineering competency could help students not only with their decisions about future career paths, but also educational decisions in college.

Contributions of the Project

There are many types of and purposes for psychological testing, including cognitive and neuropsychological testing for diagnostic purposes, behavioral testing for intervention planning, and many more (AERA, APA, & NCME, 2014). The proposed inventory falls under the category of vocational testing for personal awareness, growth, and action, and measures elements of career development (AERA, APA, & NCME, 2014). This dissertation work aims to set the foundation for developing a self-efficacy inventory of professional engineering competencies to help bachelor's and master's level engineering students to make more informed career decisions.

Specifically, the research objectives include (1) identifying the latent constructs that measure students' self-efficacy in professional engineering competency, (2) exploring the difference on self-efficacy in professional engineering competency across groups in gender, degree pursuing, discipline, and previous engineering experiences.

This research design follows the process of scale development research (Netemyer, Bearden, & Sharma, 2003). The key steps involved: (a) generating an initial pool of items to represent the expected professional competencies, (b) exploring latent constructs that measure self-efficacy for professional engineering competencies, and (c) confirming the latent constructs identified in the previous step. The data was collected at a large research university, and included both bachelor's and master's students.

There are a few highlights regarding the results of this research. First, four latent factors contribute to students' self-efficacy towards professional engineering competency. The four factors are (a) considering sustainability and societal impact during engineering design and practice, (b) using tools and technologies to solve engineering problems, (c) following health and safety rules, and (d) understanding and applying engineering economics knowledge in engineering practice. Second, there was statistically significant group difference between male and female students on F2 (use of tools) and F4 (engineering economics), as well as between students who had no extracurricular engineering projects and those who had three or more on F2 (use of tools).

The development process for SEIPEC explored the students' perceptions of professional engineering competencies that impact their self-efficacy. Results from this research also show observed gender differences in self-efficacy for professional competencies. Extracurricular engineering project experience is associated with levels of self-efficacy for certain aspects of professional competencies. This project is an initial step to develop a career assessment that measures self-efficacy for professional engineering competencies for engineering students.

As a career assessment, SEIPEC is designed for college-level engineering students (bachelor's and master's) to evaluate their subjective readiness to perform successfully in the engineering workforce. It is a unique tool that is different from other career assessments because it focuses only on engineering students' preparation for engineering careers. It can be used in a few educational settings for engineering students and mentors (e.g., academic advisors, career counselors, instructors) to engage in meaningful conversations reflecting career development plans and career decision-making.

Organization of the Dissertation

This dissertation consists of five chapters. Following this chapter is a review of literature pertaining to the development of SEIPEC. The literature review includes an overview of the importance of studying competence to help engineering students with the school-to-work transition, the operationalized definition of competency in this research. Next I discuss competency-based education, the theoretical framework used in this research (Engineering Competency Model), then using career assessments to facilitate career development. Finally, I introduce the concept of self-efficacy and explain the rationale behind connecting self-efficacy with professional engineering competency.

Chapter three provides a detailed description of the research design, including the instrumentation process used to convert the ECM model into an online survey, data collection and an overview of the sample, use of exploratory factor analysis (EFA) to identify the initial factor structure that contributed to the data variance, use of confirmatory factor analysis (CFA) to test whether the factor structure obtained from EFA explained the data variance, and one-way analysis of variance (ANOVA) to explore group differences in self-efficacy towards professional engineering competencies. Chapter four describes the results obtained from the EFA, CFA, and ANOVA analysis with tables and interpretation. Chapter five presents my understanding of and reflection on the results that emerged from the analysis, including the five-factor structure obtained from EFA, the four-factor model confirmed with CFA, and the group differences between male and female respondents, and between students with no and many extracurricular experiences. Then I discuss the application of SEIPEC and limitations of the work, as well as outlining future studies to follow this dissertation project.

LITERATURE REVIEW

In the literature review section, I first discuss the transition of new graduates from school to work to provide the context for developing SEIPEC. Then competency and competency-based education are introduced to set up the foundation for the research. Following the introduction of competency-based education is a brief discussion of career assessment and its use, then previous studies of self-efficacy among engineering students. Expanding on the rationale to study self-efficacy in professional competencies, I discuss the development and content of the Engineering Competency Model (ECM), which is used as the theoretical framework for this research. Finally, the research objectives are presented to conclude the chapter.

Why Measure Self-Efficacy for Competency?

The Transition from School to Workplace

When new engineering graduates enter the workforce, they may experience some degree of self-doubt during the transition stage (Baytiyeh & Naja, 2011). The rules learned in college to judge their quality of performance may not apply directly to the workplace (Murphy, Blustein, Bohlig, & Platt, 2010; Hettich, 2010). Many times, new graduates find that the process for success at school does not apply to the process for success in the workplace. A combination of a lack of understanding of the workplace and inaccurate expectations presents challenges to students adjusting to their new identity as a professional.

The transition process from school to work for traditional engineering college students could be challenging. First, learning is unstructured in the workplace (Hettich, 2010; Dahlgren, Hult, Dahlgren, Segerstad, & Johansson, 2006). The new graduates are used to receiving feedback as students in the form of grades or comments on their homework, exams, and projects. In the workplace, feedback is often absent or informal, and there is no clear rubric for each task assigned to a new employee. Workplace learning can occur on the job or off the job, through formal training or informal teaching. The absence of a familiar structure could pose challenges for new graduates seeking to establish clear expectations for themselves in an unfamiliar environment. Moreover, much work in the workplace requires not only technical skills but also a socio-technical understanding of the tasks (Lutz, 2017). In studying workplace learning among new engineers, Lutz (2017) found that the sociocultural integration process for new professional engineers includes many elements: people, politics, traditions, goals and values, and language. For example, a new engineer will need to “learn about what guides organizational decisions” and “learn why and how things are done the way they are” (Lutz, 2017, p. 53). Third, new engineers also face a change from school to the workplace in the level of assumed responsibilities. Learning how to align personal goals with organizational goals and understanding their roles within the organization are not as clear as understanding the expectations listed on a college course syllabus (Hettich, 2010). Bamiyeh and Naja (2011) found that this shift to more significant responsibility can cause self-doubt and anxiety for new engineers. Finally, interpersonal relationships also pose challenges for new graduates (Lutz, 2017; Chao et al., 1994). Relationships in the workplace are professional yet different from the familiar peer-to-peer and professor-student relationships in college. Unlike a more homogeneous group of people of similar age that attend the same university, co-workers in the workplace can be more diverse in terms of age, experience level, and work responsibilities. Also, the relationship between a new employee and a supervisor, although it still poses a hierarchy and power contrast, differs from the relationships that students have with their professors.

Students need to form realistic and accurate expectations for the workplace in order to experience a successful transition. Early exposure to professional work provides students with valuable personal experience to reflect on the difference between school and workplace. For example, opportunities such as internships and service-learning strengthen the connection between learning and professional practice, and students gain valuable insight into their own strengths and weaknesses (Renganathan et al., 2012; Huff, Zoltowski, & Oaks, 2016). In a study of career preparation’s impact on students’ initial success in employment, Sagen et al. (2000) found that career preparation increased the chance of successful transition from school to work when the job market was highly competitive for college graduates.

Competency

Technology-driven social development brings changes to the world of work as well as increasing demand for competent talent to fill the various job functions required across all employment sectors (Neuman, 1979). A critical concept used in human resource literature regarding talent acquisition and training is competency. In the literature, both *competency* and *competence* are used, although inconsistently (Winterton et al., 2005). According to *On Competence: A Critical Analysis of Competence-based Reforms in Higher Education* (Grant, 1979), competence is the word of choice. In the field of education, many programs that use an outcome-based approach are referred as "competence-based education" (e.g., teacher education research in the UK) or "competency-based education" (e.g., medical education research in the United States). In *Competence-based Vocational and Professional Education* (Mulder, 2016), competency and competence are explained and distinguished with some nuances. Regardless of the choice of word and its roots from various epistemological perspectives, competency is a well-recognized "fuzzy concept" that plays an important role in bridging the gap between education and the workplace (Winterton et al., 2005; Mulder & Winterton, 2017). In this project, I consider "competency" and "competence" to be interchangeable and use the expression "competency-based education" for consistency.

Competency could be interpreted through many perspectives (Le Deist & Winterton, 2005; Grant, 1979; Mulder & Winterton, 2017). Three major perspectives for the definition of competency are (a) the behaviorism approach, (b) the functional approach, (c) the integrated perspective. The behaviorist approach has been mostly recognized and promoted in the United States. Psychology professor White (1959) and many scholars who followed his study defined competence as "effective interaction (of the individual) with the environment," emphasizing the cognitive and operational skills needed for effectiveness and success in performing job duties. On the other side of the world, driven by the reformation in vocational education, UK scholars defined competence according to occupational standards, grounding it in functional analysis. The emphasis of this functional perspective of competence focuses on demonstrated ability to meet the work context expectation. A more integrated perspective on both behavioral and functional was proposed and adopted in France, Germany, and Austria. From this holistic perspective, competence is viewed both at the individual level as individual behaviors and at the functional level as required competence in an organization (Le Deist & Winterton, 2005). In this project, I operationalized the term *competency* with the consideration of the Engineering Competency Model (ECM) framework. I followed an integrated perspective with a heavier focus on the behaviorist tradition, and viewed it on an individual level rather than a collective level to define competency as a "generic, integrated and internalized capability to deliver sustainable effective performance in a certain professional domain, job, role, organizational context, and task situation" (Mulder, 2014).

Competency in Hiring

Competency plays an important role in the hiring process, when employers use competency models in various ways to select the best candidates and design training (Lucia & Lepsinger, 1999). Recruiting and retaining competent talent has been recognized as a key factor that influences an organization's success (Lucia & Lepsinger, 1999). On a basic level during hiring practices, competency models provide information about job requirements and increase the likelihood of hiring people who will succeed in a job (McClelland, 1998; Campion, Fink, Ruggeberg, Carr, Phillips, & Odman, 2011). Competency statements are widely used in job postings to describe the desired qualifications, as well as in interviews to invite candidates to demonstrate their qualification. Due to the prevalence and importance of the concept of competency in hiring practices, students should be familiar with the concept in order to prepare for a transition from school to workplace.

Preparing college students with an understanding of the workplace and professional life has a profound impact on their potential career development. Industries and employers expect successful college graduates to explore and identify the jobs that fit them, take steps to pursue opportunities, and self-advocate in the workplace (NACE, 2017). Among the eight NACE competencies for all new graduates, career management is one that might not seem obvious to college students. Career management competency is thus defined: "Identify and articulate one's skills, strengths, knowledge, and experiences relevant to the position desired and career goals, and identify areas necessary for professional growth" (https://www.naceweb.org/career-readiness). The employers' expectation for students to have career management competency highlights a significant difference between the workplace and the school setting—the fact that there is not always a clearly laid out career development route for a working professional in the same way that a plan of study exists for a student.

Competency-based hiring is favored by employers due to its practicality and flexibility in balancing hiring and training (Ennis, 2008; Lucia & Lepsinger, 1999). When competencies needed for a job are clearly identified, employers can decide on which competencies are trainable and adjust hiring strategies accordingly. In this way, hiring and training work coherently, and employers will secure the best available talent with a clear plan to train them so they can successfully fulfill their job responsibilities. Competency-based hiring ensures a systematic approach to evaluating candidates, eliminating bias about individual characteristics that are not relevant to the job, and increasing the likelihood of hiring a more diverse pool of talent (Lucia & Lepsinger, 1999). The systematic approach of evaluation is particularly crucial for ensuring fair hiring among underrepresented populations, because competencies are not associated with one's background but rather with one's capabilities.

Given the importance of competencies in the hiring process, increasing students' knowledge and awareness of them could help with preparation for the job search process. When students are equipped with a strong understanding of the concept of competency, they can better articulate their qualifications and secure a job that is a good fit. In the job search process, many employers use personal interviews to understand a candidate's fit for the position and the organization (Lucia & Lepsinger, 1999). During this process, interviewers assess whether a candidate has the potential to successfully perform the job duties.

Competency-Based Education/Learning

Competence-based education (CBE) in higher education refers to a form of thinking and practices that view the education process and outcome through the lens of desired and demonstrated student achievements (Grant, 1979). Contrary to the traditional education practice that focuses on "what was taught to the students," competency-based education emphasizes "what has the student learned." This movement from traditional knowledge-based curriculum to outcome-based higher education was driven by the need to make education more responsive to the changing needs of the workforce, as well as to increase the employability and career readiness of graduates (Mulder & Winterton, 2017).

Competency-based education has a history of more than 60 years in the United States (Barrick, 2017). Although education practices with an underpinning of competency-based education existed for a long time, the more salient historical root of such an education movement was John Dewey. Around the 1900s, two leading thinkers in education proposed a new way of looking at education at the same time. Dewey's strong advocacy for experiential learning in the field of child development went together with Prosser's advocacy for learning skills in a context close to the reality in the workplace in the field of vocational education (Barrick, 2017). Although neither approach to education was considered competency-based, both had a significant influence on later development and adoption of competency-based education in the United States.

The U.S. approach to competency-based education has a strong root in behaviorism theories. Deriving from this theoretical stance, assessment in competency-based education in the United States emphasizes an accurate measure of students' learning outcomes against the appropriate criterion. This approach allows flexibility for students' learning pace and encourages students to develop individual experiences, both of which promote a learning environment beyond the traditional classroom setting. One of the most outstanding benefits of competency-based learning is its capacity to promote students' autonomy and ownership of the learning process compared to traditional education. Although not completely incorporated into the higher education system, competency-based learning has informed programs to design more student-centered learning experiences.

Engineering education shifted from a traditional curriculum-centered model to a competency-based model with the adoption of ABET Engineering Criteria 2000. Positive changes in student learning have been seen since EC2000. Lattuca, Terenzini, and Volkwein (2006) used a mixed-method approach to evaluate how EC2000 has changed graduates' quality and skills, and found that since EC2000, more programs have focused on active learning and students' professional skills development. After the implementation of EC2000, students reported being more actively engaged in their learning and receiving more feedback on their work from instructors. An outcome comparison of 1994 and 2004 cohorts showed that when competency-based learning was implemented in engineering, students maintained their achievement in math and science and acquired stronger outcomes in areas of awareness of societal and global issues, engineering decisions, applying engineering skills, group skills, and awareness of issues relating to ethics and professionalism.

Competency Model

Competency models have been applied to multiple practices in human resources, including clarifying work expectations, hiring the best-fit talents, increasing productivity, providing a framework for performance feedback, and aligning behavior with organizational values (Lucia & Lepsinger, 1999). The concept of a model that describes all the competencies needed for a certain job or occupation was first introduced in the human resources management field as a way to help companies select and manage their talent to meet the rapid growth of technology and business (Lucia & Lepsinger, 1999). These models identify the competencies needed to operate in a specific role within a job, occupation, organization, or industry (Ennis, 2008). A competency model "describes the particular combination of knowledge, skills, and characteristics needed to perform a role in an organization effectively and is used as a human resource tool for selection, training and development, appraisal, and succession planning" (Lucia & Lepsinger, 1999, p. 5).

With the trend toward using competency in education and training, competency models have been used as a link between education and industry (Paulson, 2001; Ennis, 2008). For example, Murnane and Levy proposed "The New Basics Skills" to help students identify critical skills to achieve by the end of high school and in preparation for college (Paulson, 2001). Oblinger and Verville (1998) synthesized corporate research on industry's skill requirements for bachelor's degree recipients. In their work, problem-solving, understanding of the global economy, and basic knowledge of business have been explored extensively and identified as necessary competencies for college graduates. As indicated by Mulder's (2017) review of existing competence studies in professional education, competency frameworks have been used in many educational fields such as business, agriculture, and medicine. Competency models are not a laundry list of competencies; rather, they present competencies for specific jobs or industries, holistically. Ennis (2008) suggested that future researchers treat competency models as viable tools to prepare current and future workforces.

A few educational studies have explored core competencies that help current students prepare for aspects of their future careers (Bornstein, Heritage, Chudak, & Tamblyn, 2018; Hyland, 1993; Jesiek, Zhu, Woo, Thompson, & Mazzuro, 2014). Bornstein et al. (2018) developed core competencies for health service and policy research doctoral students. The core competencies offered insights into potential career paths and suggestions for maximizing students' impact in the health profession. In teacher education, Hyland (1993) argued that using competency models based on the concept of "expertise" helps to produce reflective practitioners who can "enhance the status and quality of teaching in school and colleges" (p. 123). Jesiek et al. (2014) conducted a study of global competencies for engineers, and found that global engineering competency consists of technical coordination, engineering cultures, and ethics, standards, and regulations. Because competence-based education focuses on equipping students with certain skills, it lays the foundation for paths to experts. In the field of engineering education, ABET's "Criterion 3-Student Outcomes" in the General Criteria for Baccalaureate Level Programs is a sample list of competencies expected of an engineering student (ABET, 2019). The expected education outcomes of ABET address not only technical engineering skills such as engineering knowledge, but also professional skills such as teamwork and communication (Shuman, Besterfield-Sacre, & McGourty, 2005; ABET, 2019).

Assessment of Professional Competencies in Engineering Education

In competency-based education, assessment is a crucial component that can provide an understanding of the learning outcome and enhance students' learning by informing pedagogy. Moreover, assessments become a form of learning as students receive personalized feedback and engage in self-reflection (Wesselink, Biemans, Gulikers, & Mulder, 2017). Assessment strategies for competency-based education come in various forms, including traditional quizzes and exams, 360-degree assessments, behavioral assessments, portfolios, and more (Henri et al., 2017). The assessment strategies used in competency-based learning vary among universities, and not much research has been done to identify best practices (Henri et al., 2017). Assessment strategies also vary according to the nature of the competency to be assessed, as well as the assessment objective. One promising comprehensive assessment strategy is portfolios, which are suitable for measuring holistic competencies. This strategy has been purposefully integrated into many programs to enable students to develop a collection of evidence of their acquired competencies (e.g., Brumm, Mickelson, Steward, & Kaleita, 2006). Competency-driven portfolios ask students to take the initiative in the assessment process, and involve much self-reflection. Using this type of assessment, students are expected to learn how to map their learning outcomes with the required competencies. In addition to portfolios, other assessment strategies have been adopted to measure students' competency in various contexts. The 360-degree assessment uses multiple sources to generate feedback from self, peers, instructors, and professionals. Online assessments refer to the use of electronic platforms, and surveys are often used to assess non-technical competencies as well as to capture the indicators of students' learning outcomes (Henri et al., 2017).

Professional competencies are not only hard to teach (Walter & Radcliffe, 2007) but also hard to assess (Brumm, Mickleson, Steward, & Kaleita, 2006). Brumm et al. (2006) and Brumm, Henneman, and Michelson (2006) found that workplace competencies are difficult to acquire in the traditional classroom setting, and argued that it is more appropriate to teach these competencies in an experiential learning environment. Shuman, Basterfield-Sacre, and

McGoutry (2005) identified three main obstacles for authentic, effective assessment of non-technical engineering professional skills (e.g., teamwork, ethics, and communication).

First, the nature of professional skills creates challenges for a universal definition of the competencies as educational outcomes. Unlike assessing students' understanding of a technical term in engineering, where most instructors share a common understanding, professional skills are normally constructed socially, where people from various contexts might operationalize them differently. Second, authentic learning of professional skills requires high-level integration of various educational experiences in engineering programs, leading to a need for multi-source assessments. Although incorporating multi-source assessments is effective in increasing the quality of assessment, implementation often requires more time and investment than a single source assessment. This compromise in expediency may lead to resistance to launching such assessments due to lack of resources from engineering programs. Third, the acquisition of some competencies for awareness of social, environmental, and global factors in engineering practice requires student support beyond engineering programs. These competencies focus on influencing students' aims and attitudes as they decide how to apply their engineering skills in order to have broad influence. Also, the appropriate assessments for these skills ask for the use of assessment methods, such as non-intrusive observation. As for the second obstacle discussed above, assessing a student's attitude, values, and behaviors on topics of environmental and social awareness requires well-trained professionals and more resources than a traditional exam. A self-assessment tool that measures professional competencies answers the call for multi-source tools and tools that require low resources.

Career Assessment and Use of Assessment in Counseling

Career assessment includes a variety of tests pertaining to interests, values, career development, career maturity, and career decision-making (AERA, APA, & NCME, 2014). Career assessments are administered and interpreted by career counselors or other vocational guidance professionals to help individuals with career decision making and other career concerns. For example, many U.S. university career services professionals administer the Strong Interest Inventory to help students explore career interests. Results from the Strong Interest Inventory provide students with insights by identifying their interest areas and revealing their degree of interest in certain areas or occupations. With the help of a career counselor, students learn to better navigate the many majors that a university offers, as well as multiple career paths in the workplace.

Career assessments are different from the concept inventory and other exams that test students' learning outcomes (for example, measuring whether the student has mastered key knowledge and skills in an engineering technical course). Career assessments are a type of psychological assessment that use self-reported data to provide information that helps individuals to better understand themselves. This process often helps students to identify their own strengths and weaknesses, clarify their goals and priorities, and move forward in making informed decisions.

In the university context, career counselors use results to stimulate conversations with students when they need help choosing a major, choosing a career path, or addressing other career development concerns. The results of the career assessments are diagnostic to help understand the situation, but not prescriptive to restrain what a student must do. Each individual's career situation is unique and could be influenced by many things, including interpersonal and environmental factors (Patton & McMahon, 2006). Career assessments can be used as a subjective evaluation to facilitate engineering students' learning, to supplement traditional objective tests of skills and knowledge, and to make the learning process more individualized and student-focused.

In the current post-secondary education ecosystem, career services provide both in-person and virtual services to serve students regarding their individual career development concerns, besides acting as a bridge to connect employers and students for full-time and internship opportunities (Venable, 2010). The process of one-on-one career counseling is a working alliance formed between the counselor and the student to empower the student to make career choices and decisions (Dey & Cruzvergara, 2014). Unlike teaching, counseling embraces a constructivist perspective and emphasizes the student's motivation and autonomy to achieve their identified goals (Axinte, 2014). Topics covered in career counseling vary among students but generally pertain to career exploration and selection, job search readiness preparation, and other career development issues. Like one-on-one counseling sessions, career development courses were found to have a positive impact on students' career decision-making self-efficacy in addition to fewer perceived decision-making difficulties for college students (Reese & Miller, 2006). Helping students to better leverage the career resources provided by universities will bring positive change to their career development journey.

Self-Efficacy

Self-efficacy refers to one's belief in their capability to complete particular tasks (Bandura, 1986). Grounded in social cognitive theory, self-efficacy can be defined as "beliefs in one's capabilities to mobilize the motivation, cognitive resources, and courses of action needed to meet given situational demands" (Bandura, 1977; Bandura, 1997). Previous research suggests that high self-efficacy contributes to how people think, feel, and act. For example, a person with high self-efficacy in career decision making is more likely to make choices and take action to research jobs and proceed to get them (Betz, Hammond, & Multon, 2005).

Self-efficacy beliefs can change over time, and there are four principal sources of self-efficacy (Bandura, 1997). They are enactive mastery experience, vicarious experience, verbal persuasion, and physiological and affective status. Enactive mastery experience serves as an indicator of capability and appears to be the most important source of self-efficacy because it provides the most authentic evidence of whether or not a person can accomplish certain tasks. Vicarious experience alters efficacy beliefs through transmission of competencies and comparison with the attainments of others, where modeling serves as an effective way to promote self-efficacy beliefs. Verbal persuasion and related social influences have limited power to create enduring increases in one's perceived abilities, but still could have a positive impact on one's self-efficacy belief, especially when someone doubts their competency. Physiological and affective status can impact one's self-efficacy in that when people perceive lower stress levels and enhanced physical status, their self-efficacy beliefs also alter.

Self-efficacy is context- and domain-specific as Bandura (2006) suggested that there is little explanatory and predictive value if the construct of self-efficacy is not defined and appropriately measured. He suggested that self-efficacy is measured in reference to specific behaviors and not as a personal trait. Pajares (1996) also confirmed that a Specific Self-efficacy Scale (SSE) has better predictive power than a General Self-efficacy Scale (GSE).

Previous studies of self-efficacy for engineering students have revealed the strong impact of different kinds of self-efficacy on many significant aspects of a student's college career, including motivation, academic performance, persistence, career interests, choice, and so on (Lent, Sheu, Singley, Schmidt, Schmidt, & Gloster, 2008; Lent, Lopez, Lopez, & Sheu, 2008;

Mamaril, Usher, Li, Economy, & Kennedy, 2016; Marra, Rodgers, Shen, & Bogue, 2009). A study of engineering students' identities and persistence found that self-efficacy measured by math and science self-efficacy has predictive power for students' engineering identities. Students' self-efficacy beliefs are substantially related to their academic goals (Brown, Tramayne, Hoxha, Telander, Fan, & Lent, 2008). For example, when a student has high self-efficacy beliefs, they are likely to set high academic expectations and put forth effort to realize the goal. Self-efficacy is a strong predictor of academic performance and could mediate the influence of other determinants (Brown et al., 2009; Pajares, 1996; Mamaril et al., 2016).

One model that summarizes the impact of self-efficacy on career development is social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994). Figure 1 shows the constructs and their relationships. SCCT provides a perspective on understanding the individual cognitive process of career decision making while also incorporating the influence of environmental factors. In this model, self-efficacy plays an important role and influences interest, choice goals, choice action, and performance. For example, when students have high self-efficacy in their ability to fulfill engineering course requirements, they are more likely to develop an interest in engineering and want to pursue a degree in engineering. Expecting to do well in engineering courses, they prioritize engineering as a college major instead of other disciplines. Also, because students have high confidence, they are more likely to participate in activities that are engineering-related. Because pursuing an engineering degree is the student's goal, they participate in engineering-related activities to become better acquainted with the field. When students spend much time doing engineering-related tasks, they are likely to develop cognitive skills that support performance achievement in more engineering tasks and tests.

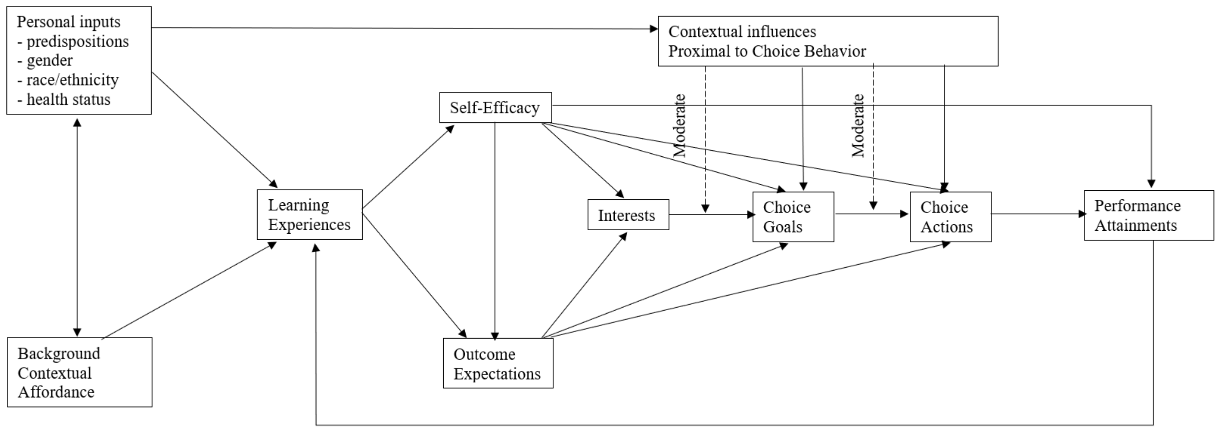

Figure 1. Relationship between Self-efficacy and Other Important Concepts in Career Decision-making Process, adopted from Social Cognitive Career Theory (Lent, Brown, & Hackett, 2002)

The model of SCCT has been tested by different groups for its fit, and evidence shows that the model fits across genders, educational levels, and different institutions (Lent et al., 2008b). Following the theoretical assumptions of social cognitive theory and social cognitive career theory, I summarize some previous self-efficacy research that focuses on engineering students in the college setting. The following constructs for self-efficacy will be discussed: gender, discipline, and development.

Gender. According to the American Society of Engineering Education's (ASEE) annual report, women engineering students as well as degree holders make up about 20% of the engineering population in the United States (Yoder, 2017). This number has been low, and some engineering fields suffer from even lower numbers of female students and graduates. The gender difference has inspired many educational researchers to examine this concern from multiple perspectives (e.g., Betz & Hackett, 1983; Hutchison et al., 2006; McKenzie, 2016). Hutchison et al. (2006) found that women engineering students value help and support from the academic environment more than their male counterparts do. Female students were found to have lower self-efficacy compared to their male counterparts in a few aspects (e.g., lower math self-efficacy, Betz & Hackett, 1981, 1983; lower self-efficacy starting in their first year, Besterfield-Sacre et al., 2001). In a longitudinal study, Marra et al. (2009) found that women engineering students experience strong growth in their self-efficacy while their sense of inclusion goes down.

Meanwhile, the gender difference in self-efficacy is not prevalent on all aspects because some research findings implied no gender difference in various aspects of self-efficacy.

Concannon and Barrow (2009) used a modified subscale of the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) to study undergraduate students, and found no difference in self-efficacy when compared by gender alone. As Bandura (1977, 1997, 2006) proposed, self-efficacy has predictive and explanatory power when it is geared towards specific behaviors. Due to the nature of self-efficacy measurement, gender differences in the self-efficacy of particular behaviors would not necessarily transfer to other behaviors.

Developmental. Traditional college students (enrolled directly after high school) go through developmental transitions in their career goals and professional identities (Skorikov, 2006; Murphy et al., 2010; Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). Findings on developmental trends in various aspects of self-efficacy among college engineering students indicate that engineering students' self-efficacy may or may not vary across year levels (Mamaril et al., 2016; Marra et al., 2009), but some specific engineering self-efficacy was positively associated with experience (Carberry, Lee, & Ohland, 2010). Mamaril et al. (2016) found no significant difference in engineering self-efficacy, both general and skills-related, as measured when they control for students' year level. Marra et al.'s (2009) study also found that female engineering students' self-efficacy changes were not impacted by year level. While no difference in self-efficacy measurements across year levels was identified, students' identities as engineers strengthened as they progressed in their college career. In a qualitative study, Stevens et al. (2008) found that students' identification with engineering continues to grow as they further their studies in engineering. Meyers, Ohland, Pawley, Silliman, & Smith (2012) found that first-year engineering students are less likely to identify themselves as an "engineer" compared to the more advanced students in their second, third, and fourth years of study. Referring back to the sources of self-efficacy, an experience of mastery is a more accurate concept to correlate with self-efficacy than students' year level.

Discipline. Many differences exist among engineering majors, including students' persistence and retention (Ohland, Sheppard, Lichtenstein, Eris, Chachra, & Layton, 2008; Lord, Layton, & Ohland, 2011) as well as departmental culture (Godfrey, 2015). Most educational studies of engineering students do not distinguish among students in different engineering disciplines. Previous studies either treat engineering disciplines as a homogenous group or combine engineering students with students from science, math, and technology as "STEM students." Godfrey (2015) proposed that when examining engineering disciplinary culture through the lens of “engineering way of thinking,” “engineering way of doing,” and “being an engineer,” each engineering discipline has its unique cultural characteristics that are easily distinguished from the others. Studies of students’ migration (Lord et al., 2011) and student outcomes across disciplines (e.g., Ohland et al., 2008; Lord et al., 2014; Main, Xu, & Dukes, 2018) indicate that different engineering disciplines attract different groups of students with regard to gender, race, and ethnicity. Ngambeki (2012) found that students’ decision-making processes for choosing engineering as a field of study are different from the process for choosing an engineering discipline. Personality, value, and goal differences were significant among students who chose different engineering disciplines, which supports heterogeneity within the engineering student population.

Previous research on self-efficacy for engineering students supported the SCCT theory. Self-efficacy has explained students’ academic achievement, interests, and choices, in addition to shedding light on the gender imbalance within the engineering population. To further extend this line of understanding, engineering students’ self-efficacy, development, and validation of the Self-efficacy Inventory of Professional Engineering Competency would increase understanding of students’ self-efficacy with regard to professional competencies.

Previous Self-Efficacy Inventories

Previous researchers have examined and developed self-efficacy scales related to workplace competencies (Raelin, 2010) as well as engineering students (Mamaril, 2014; Lattuca & Terenzini, 2014). Raelin’s (2010) Work Self-Efficacy Inventory (WS-Ei) measures seven dimensions including learning, problem-solving, pressure, role expectations, teamwork, sensitivity, work politics, and overall work self-efficacy. This scale aims at measuring workers’ confidence in managing workplace experiences. The sample used for the development of the survey included engineering, business, and pharmacy undergraduate students for EFA and continuing education students for CFA. The overlap between the WS-Ei and the ECM included problem-solving and teamwork. Mamaril’s (2014) Engineering Self-Efficacy Scale includes a unidimensional general engineering self-efficacy scale, and a three-factor engineering skills self-efficacy scale measured the tinkering, designing, and experimentation skills of undergraduate engineering students. The longitudinal assessment of engineering self-efficacy (LAESE) (Marra & Bogue, 2006) is a validated self-efficacy assessment for college and high school students. It measures self-efficacy in the following areas: barrier situations, expected outcomes, workload expectations, the process of choosing a major, career exploration, and role models' influence on decisions.

Besides the self-efficacy inventory, other assessments of professional engineering competencies exist. For example, Lattuca and Terenzini's (2014) survey instrument to benchmark students against the criteria of "Engineer of 2020" measures students' perceived ability in engineering skills and their perceptions of professional skills. The competencies measured by Lattuca and Terenzini (2014) include applying math and science; defining problems and generating design solutions; managing a design project; knowledge of engineering contexts, communication, teamwork, leadership, interdisciplinary knowledge, and skills; and recognizing perspectives. Several items/concepts in the "Engineer of 2020" student survey and Tier 3 and 4 from ECM overlap: problem-solving, designing, coordinating and managing, and teamwork.

The aforementioned assessments and inventories all provided a unique perspective to assess either engineering related (LAESE, Engineering Self-efficacy Scale) or workplace-related (WS-Ei) self-efficacy. Following in the steps of previous researchers, I am developing SEIPEC for measurement of self-efficacy in workplace competencies for engineering students, where previous work only addressed self-efficacy for either engineering learning or a generic workplace.

Why Self-Efficacy of Professional Competency?

Self-efficacy of competency has the potential to impact three key activities in engineering students' career development at a critical stage of post-graduation destination: choice, access, and performance. Choice is related to students' self-efficacy for engineering competencies because students with high self-efficacy towards their engineering competencies are more likely to keep engineering as a career option (Lent, Brown, & Hackett, 1994; Lent, Sheu, Singley, Schmidt, Schmidt, & Gloster, 2008). Access is related to engineering competencies because the students who understand competencies and articulate their competencies well in the recruiting process are more likely to be favored by employers, resulting in greater access to engineering jobs. Performance is related to self-efficacy towards engineering competency because competencies are widely used in human resource development systems. So when students intentionally use competency to guide their professional development, they have a better chance of performing well in the workplace, which requires self-learning in both structured and unstructured environments.

Using reflection in education has been recognized for its contribution to cultivating insight, focus, concentration, and empathy, which ultimately improves students' emotional intelligence (Chaskason, 2011). The development of emotional intelligence contributes to the objective of becoming aware and preparing for the transition from college to workplace. Measuring self-efficacy for professional engineering competency provides self-knowledge that enables students to engage in reflection with regard to their professional skills. With better self-knowledge about their personal strengths and a deeper understanding of the desired workplace competencies, students can make more informed decisions when choosing elective courses, extracurricular involvement, and internship opportunities, all of which would contribute to better preparation to enter the workforce after graduation. A concept map is attached in Appendix A to illustrate the relationship between the concepts.

Theoretical Framework

I choose the Engineering Competency Model as the theoretical framework because it provides a model with a comprehensive list of engineering competency requirements for professional engineers. Consisting of more than 600 competency statements, ECM "promotes an understanding of the competencies that are essential to educate and train a globally competitive engineering workforce." (Leslie, 2015, p.2) ECM establish a guideline for employers, educators, career counselors. and current and future engineers, and each of the groups can use the model in different ways according to their needs.

Background and Process for Development of ECM

This research uses ECM as a framework for identifying expected competencies for professional engineers. ECM was initiated in 2013 by the American Association of Engineering Societies (AAES), partnering with the Employment and Training Administration (ETA) under the U.S. Department of Labor (USDOL) ("Development of Engineering Competency Models Continues," 2016). AAES is a multidisciplinary organization of engineering societies that formed a special group in 2013—the Lifelong Learning Working Group (LLWG)—with the goal of advancing the engineering profession's impact on the public good. ECM was identified by LLWG as the key priority to help member associations understand the knowledge and skills engineers need.

The Engineering Competency Model was designed with the goal of guiding a few key groups to develop future engineers. The first group is industry leaders, employers, and human resource professionals. ECM helps this group with selection and performance evaluation. The second group is educators, for the development of competency-based curricula and training. The third group is workforce professionals and career counselors, who can use ECM to guide exploration and planning. The fourth group is current and future engineers, who can obtain a clear understanding of the requirements necessary to enter, advance, and succeed in the industry.

During the collaboration between AAES and ETA, both groups provided their expertise. ETA assigned a designated research group for the project, and AAES provided documents for review—accreditation criteria, bodies of knowledge from various engineering societies, the Project Lead the Way outline, and curricula and related resources from academic institutions across the United States. Throughout the process, the research group sought feedback and input from stakeholders on both the education side and the employment side. For example, with feedback from engineering educators and engineering industry leaders, the research group proposed a model for all societies under AAES through an interactive seminar designed to gather further input. After presenting the development process and facilitating discussion on the draft model at the webinar, the research group distributed a survey to solicit feedback from the engineering communities. Feedback from more than 100 leaders was incorporated and updates and revisions were implemented, then the research group published ECM in May 2015.

I chose ECM as the foundation from which to develop the self-efficacy inventory because of endorsements from experts, as well as the comprehensive engineering competencies included in the model. ECM can inform program administrators and instructors about developing programs to help students bridge the gap between academics and employment. Engineering students can use this as a reference to understand professional engineers' skills, abilities, and knowledge.

Description of ECM Structure and Content

ECM consists of four layers in the shape of a pyramid that follow the ETA basic industrial competency model, the Building Blocks Model (ETA, 2017). The building block model provides the foundation for outlining professional competencies across many industry and occupation, but the ECM only specify competencies regarding the first four layers of the model. In this 4-tier pyramid shape, the higher-level competencies do not necessarily mean higher cognitive or skill levels but rather indicate the specificity of these competencies to a job, industry, or occupation (Ennis, 2008; AAES, 2015). Tier 1 is the foundational level. Tier 2 and Tier 3 both consist of competencies required across different occupations. Tier 4 represents industry-specific competencies for engineers. The four tiers of competency are personal effectiveness, academic, workplace, and industry-wide. Figure 2 provides a visual representation of the four layers of the Engineering Competency Model. Appendix B presents the full structure of the Engineering Competency Model.

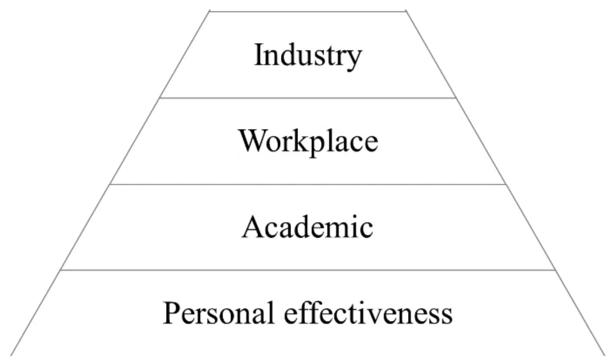

Figure 2. Basic Structure of the Engineering Competency Model

In this project, I used the competency statements from Tier 3 workplace competencies and Tier 4 industry-wide technical competencies, because both tiers represent the professional competencies expected for the engineering workforce. Tier 1 and Tier 2 were not used in this research due to two reasons. Firstly, using ECM to create a self-efficacy inventory requires collecting and analyzing empirical data, so the length of the survey will impact the feasibility of data collection. Due to this reason, an initial survey of 600 questions would create a significant challenge for survey data collection. Secondly, Tier 1 and Tier 2 focuses on personal effectiveness and academic competencies. When compared with Tier 3 and Tier 4, Tier 1 and Tier 2 are less specific towards professional engineering work. A more detailed instrumentation process of the ECM Tier 3 and Tier 4 is shown in the methods section.

Table 1 shows the competency categories included in ECM Tier 3, and Table 2 shows the competency categories in Tier 4. Tier 3 consists of ten subcategories of competency statements that are required for effective work in the workforce, such as teamwork, planning and organizing, and working with tools and technologies. The competency statements in Tier 3 are general workplace competencies within the context of professional engineering work. Tier 4 consists of ten competency categories that are specific to professional engineering work, such as engineering fundamentals, design, quality control, and engineering economics. The competency statements in Tier 4 represents the engineering skills required for professionals at the workplace. Table 1 and Table 2 provide the working definition for each competency categories in the ECM according to AAES and ETA.

Table 1. Competency Categories in ECM Tier 3

Workplace competency areas	Definition
Teamwork	Working cooperatively with others to complete work assignments.
Client/Stakeholder Focus	Efficiently and effectively addressing the needs of clients.
Planning and Organizing	Planning and prioritizing work to manage time effectively and accomplish assigned tasks.
Creative Thinking	Generating innovative and creative solutions.
Problem Solving, Prevention and Decision Making	Generating, evaluating, and implementing solutions to problems.
Seeking and Developing Opportunities	(definition missing from the model)
Working with Tools and Technology	Selecting, using, and maintaining modern engineering tools and technology, including adaptive tools and new technology, to facilitate work activity.
Scheduling and Coordinating	Making arrangements that fulfill all requirements as efficiently and economically as possible.
Checking, Examining, and Recording	Entering, transcribing, recording, storing, or maintaining information in written or electronic/digital format, including adaptive devices and software.
Business Fundamentals	Using information on basic business principles, trends, and economics.

Table 2. Competency Categories in ECM Tier 4

Industry-wide competency areas	Definition
Foundations of Engineering	Engineering fundamentals and its interactions with society.
Design	The process of devising a system, component, or process to meet desired needs.
Manufacturing and Construction	The process by which materials are converted or assembled into higher value products.
Operations and Maintenance	The setup, operation, control, maintenance and improvement of technology that supports production to meet client requirements.

Table 2. (continued)

Industry-wide competency areas	Definition
Professional Ethics	Displaying strong engineering ethics by evaluating and applying the merits, risks, and social concerns of activities in engineering.
Business, Legal and Public Policy	The activities associated with business management and operations and the relevant local, state, federal, and international laws and regulations that impact engineering.
Sustainability and Societal and Environmental Impact	Meeting the needs of the present without compromising the ability of future generations to meet their own needs.
Engineering Economics	Economics for application to engineering projects.
Quality Control and Quality Assurance	Ensuring product and process meets quality requirements as defined by client specifications.
Safety, Health, Security and Environment	Complying with standards and procedures for a safe, secure, and healthy work environment.

Research Objectives

In their discussion of further utilizing the concept of self-efficacy to facilitate research and practice in career counseling and career development, Betz and Hackett (1983) advocated for more studies of interventions based on career self-efficacy. The SEIPEC instrument is a response to this call. At present no self-efficacy inventory measures professional engineering competencies for engineering students. Although self-assessment has been critiqued for being impacted by people's metacognition and for potentially becoming inflated when people rate themselves higher than their actual ability (Falchikov & Boud, 1989; Nuhfer, Fleisher, Cogan, Wirth, & Gaze, 2017), we also see strong evidence of the influence of self-efficacy on engineering students' career interests, choice, actions, and performance. In an ever-changing world of technological innovation, engineering work is becoming increasingly diverse in terms of work content, as well as required abilities, skills, and knowledge. With a focus on the school-to-work transition and an aim to increase student levels of career readiness, SEIPEC combines two important concepts: professional competency and self-efficacy. It serves as a tool to measure students' belief in their ability to perform tasks related to professional engineering work. Both self-efficacy and competency share the underlying implication of "capability of doing something," where self-efficacy measures one's belief and competency refers to the action/skills.

The research questions underlying the development of SEIPEC are (1) What are the latent factors that contribute to engineering students' self-efficacy in professional engineering competencies? (2) Which questions can be used to measure engineering students' self-efficacy in professional engineering competencies? Also, this research project explored group differences in self-efficacy in professional engineering competencies. Specifically, I explored the difference in self-efficacy in professional engineering competency for (a) gender, (b) degree pursuing (bachelor's and master's), (c) disciplines, (d) internship experience, (e) co-op experience, (f) academic engineering projects, (g) extracurricular engineering projects, and (h) other work experience. In the next chapter, I will describe the research design for combining self-efficacy questions with ECM statements and converting the questions into a validated assessment tool.

METHODS

This section will first describe the development of self-efficacy scales, with a focus on ensuring the accurate assessment of self-efficacy, as well as reliability and validity in scale development. Then I will summarize the instrumentation process of converting competency items from ECM into questions to assess self-efficacy for professional engineering competencies. The result of the instrumentation process is also presented in this chapter.

Following the instrumentation process is the data collection and sample description for the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA and CFA are important steps in scale development to explore the latent factor structure and finalize the scale. The decisions of the analytical approach for EFA and CFA are presented. Then, I will discuss using ANOVA to identify the differences across groups regarding their self-efficacy towards professional engineering competency. Lastly, the limitation of the research design and implementation is discussed.

Self-Efficacy Scale Development

In the development of a self-efficacy scale, Bandura (2006) highlighted two important rules to follow. First, the measurement of self-efficacy needs to be more specific rather than universal. Instead of measuring self-efficacy as a trait, Bandura (2006) and Bong (2006) suggested measuring specific behaviors. In the development of SEIPEC, I followed Bandura's suggestions by measuring students' self-efficacy for specific engineering competencies using competency statements from the Engineering Competency Model (AAES, 2015), which include expected competencies for professional engineers in the workplace.

The second rule in developing a self-efficacy scale is to avoid conflating self-efficacy with other self-referent beliefs, such as self-esteem or self-concept. The most significant difference between self-efficacy and other constructs is that self-efficacy represents context-specific perceived capability. To operationalize the second rule, it is not appropriate to ask a student how well they master a specific task, but instead, one must ask them about their confidence in mastering a specific task. A self-efficacy inventory does not assess whether a person can perform an activity occasionally, but whether the person has the confidence to accomplish an activity.

Once self-efficacy is defined as confidence in mastering a task and is measured to a specific context, there are a few more issues to consider when developing self-efficacy scale items. The first is to clarify the level of specificity, which is the level of detail included in describing an activity. In this research, I started with the ECM competency statements, where each of the competency statements represents a skill or task that is expected from professional engineers. Second is to determine the target of prediction and the judgmental interval for the self-efficacy rating scale. For the judgmental interval, Bandura (2006) suggested using a scale of 0-100; however, considering the fact that students need to answer close to 200 questions, this might be discouraging for some of the participants. A common practice for other self-efficacy scales (Worthington & Whittaker, 2006) is to use a 5-point or 7-point scale. Buttle (1996) and McKelvie (1978) suggested that using a 5-point scale has strong statistical power and can help to increase response rate and reduce fatigue. In this study, I used a 5-point scale to reduce cognitive complexity for the participants, thus decreasing potential survey fatigue.

Following guidance from Netemeyer et al. (2003), scale development included four significant stages. First, it is important to clarify the constructs being measured and decide on the content domain. In this project, the construct being measured is professional engineering competency, which includes many competency statements according to the ECM framework. Second, using previous literature and theory, the researcher needs to come up with the initial item pool with a focus on content validity. Because the ECM was developed by a group of experienced researchers from the U.S. Department of Labor with input from experts in the industry and higher education, I considered the items in the initial pool to have strong content validity. Third, the researcher collects empirical data and applies exploratory factor analysis to explore the latent constructs, generate initial factor structure, estimate validity, and check internal consistency. Last, using the results from the exploratory factor analysis in stage three, the researcher should collect more data to analyze items, confirm the scale structure, and further test validity. The data in this dissertation study were collected in one round and randomly split in half. Half of the data was used for EFA and half for CFA.

Ensuring validity and reliability is critical in the scale development process. Reliability refers to the consistency of measurement, that the factor structure obtained from EFA and CFA should not change when testing a different sample (Netemeyer et al., 2003). Two broad types of reliability in psychometric literature are test-retest reliability and internal reliability, and both are important in scale development. Internal reliability provides evidence for judging relatedness among items in a scale, and could be measured using Cronbach's α (Cronbach, 1951). A high Cronbach's α indicates strong internal consistency, thus supporting strong reliability for the items within a scale.

Construct validity refers to how well a measure represents the operationalized measure truly reflects the concept being investigated (Peter, 1981). In this research, two types of validity were used as evidence to ensure construct validity: translational validity and criterion-related validity (Netemeyer et al., 2003). In the initial development stage of SEIPEC, I focused on the translational validity, which includes content validity and face validity. Content and face validity reflect the extent of operationalization of the intended construct, which is self-efficacy for professional engineering competency in this project (Trochim & Donnelly, 2001). Specifically, content validity focuses on how well the measurement represents the target construct from the perspective of meaning and theory. Face validity focuses on how well measurement users perceive the measurement. Evidence of face validity is provided through post hoc evaluation after the content validity is established. In this project, evidence of content validity is provided by the adoption of ECM. ECM provides strong evidence for content validity because it is developed and reviewed by experts on the professional competencies required for engineers. The initial item pool of SEIPEC questions is based on ECM competency statements. Face validity is provided through interview with the participants who were engineering students. The participants provided me with feedback to evaluate the wording and clarity, clear instructions, and ease to answer (Netemeyer et al., 2003; Nevo, 1985). The next section presents the process and results of establishing face validity.

In the discussion of the EFA and CFA process, I used criterion-related validity to gather evidence for the construct validity of the scale, including convergent and discriminant validity. The following sections in this chapter provide a detailed explanation of the scale development process.

Item Instrumentation

As introduced in the previous chapter, the competency statements for professional engineers in ECM were suggested and approved by industry leaders and engineering educators (Leslie, 2015). ECM provides a strong foundation for this scale because it captures experts' views of engineering competencies, thus providing strong content validity. Building on ECM, I converted the competency statements into the initial pool of self-efficacy items. Consistent with Bandura (2006), each self-efficacy question started with “How much confidence do you have in completing the following tasks?” followed by a competency statement adopted directly from ECM. Then, consistent with Betz and Taylor’s (2012) Career Decision-making Self-efficacy scale, a 5-point confidence level scale was used to evaluate participants’ level of confidence regarding each professional competency. The five confidence levels were: 1 = no confidence; 2 = very little confidence; 3 = moderate confidence; 4 much confidence; and 5 = complete confidence.

After converting ECM competency statements from Tier 3 and 4 into self-efficacy questions for SEIPEC, I collected empirical data to increase the face validity through interview, and ensure construct validity through factor analysis. I obtained IRB approval to start data collection. Before the interviews with the participants, I first worked on increasing the clarity of the questions. Due to the complexity of ECM, there were many double-barreled questions where a question asked a question that touched upon more than one issue but only allowed for one answer. I identified the double-barreled questions and rephrased them to reduce confusion. In this process, I also worked with professional writing consultants to increase the clarity of the sentences by deleting unnecessary modifiers, breaking up long sentences, and replacing perplexing words. No competency statements were removed in this stage. Then I developed one question for each competency with the prompt “Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job. Read each statement and rate your level of confidence. There are *14* tasks associated with *teamwork* on this page. How much confidence do you have in completing the following tasks?” The prompt was followed by a specific competency statement and a 5-point confidence scale. After this process, I created a paper copy of the self-efficacy inventory with 267 self-efficacy questions. The questions were organized into 20 groups as in the ECM Tiers 3 and 4.

Pilot Study Design to Increase Face Validity

Because the inventory was designed to help engineering students and young professionals, I recruited a diverse group of participants to take the survey and provide feedback on the face validity of the survey items. This process helped ensure that the wording was understandable for those taking the assessment. Using a convenience sampling strategy, I recruited eight students during this phase to help increase the clarity of the items. The eight students came from six engineering disciplines (mechanical, electrical and computer, biomedical, industrial, aerospace and aeronautical, and civil). Electrical and computer had two representatives, so did aeronautical and astronautical engineering. Each of the other disciplines had one representative. Two graduate-level and six undergraduate-level students were included, and there were six native English speakers as well as two students for whom English is their second language. Six of the students participated in one-on-one interviews, and two were interviewed as a group. Among the eight participants, there were three female students and five male students.

In each of the interviews, I briefly shared an overview of the research project, provided instructions for the interview process, and encouraged participants to provide feedback on the survey. Following the introduction, I gave each participant a paper copy of the survey and asked them to take the survey. After every two pages, we paused and identified the survey items they considered hard to answer. At the end of each session, I asked for the participants' general feedback on the following: (a) On a scale from 0-10, how easy was it for you to understand the survey items? (b) How easy was it for you to rate the level of confidence? (c) Which categories were easy for you to relate to? (d) Which categories of competencies were most challenging to answer? (e) What experiences do you refer to when you think of these questions? (f) Is there other feedback you'd like to provide for the survey? After the first four interviews, I incorporated the feedback and updated the survey given to the latter four participants. Then I integrated all the feedback, transferred all the survey items to an online survey platform (Qualtrics), and added some questions regarding demographics and students' engineering experiences. A complete copy of the online survey is attached as Appendix C.

Results of Pilot Study on Increasing Face Validity

After adopting the items from ECM Tier 3 and Tier 4 and converting them into self-efficacy questions, I obtained face validity through individual interviews with students. After getting feedback from a student, I implemented some changes and used the updated question list with the next student. Through this process, I reached an initial item pool of 191 items under 16 categories. The following paragraphs articulate the few changes made to the inventory items.

First, the number of categories was reduced from 20 to 16 due to the overlap of items across various constructs. All eight participants expressed some level of concern that the competency group “seeking and developing opportunities” in Tier 3 was confusing and difficult for students to relate to their experience. The questions in this category included statements on “maintaining perspective” and “marketing,” such as “uphold the organization through building and maintaining client/stakeholder relationships” and “formulate ideas on how to pursue opportunities and share them with appropriate personnel.” Then some participants suggested that a few competency groups should be combined due to the conceptual overlap among them. The competency groups “planning and organizing” and “scheduling and coordinating” were combined into one group. Similarly, “business fundamentals” and “business, legal and public policy” were combined, and “manufacturing and construction” and operation and maintenance” were combined. All of the items were retained when the groups were collapsed.

Second, the wording was simplified significantly by eliminating unnecessary modifiers such as adverbs and clauses. When a competency statement was long, I worked with the interviewees to either break it down into two or more statements or retain the core description of the statement. For example, one competency statement in Tier 4 was “Contribute to the development of alternatives by analyzing the pros and cons of alternative design options, preparing those design options, and assisting in the selection of an optimized design alternative.” The statement was broken into three separate statements: (a) contribute to the development of alternatives by analyzing the pros and cons of alternative design options, (b) assist in the selection of an optimized design alternative, (c) prepare design options. Third, when a statement was identified by multiple students as “confusing and hard to understand”, I worked with the participants to either rephrased the statement or deleted it. For example, one competency statement in Tier 4 was “operate with a triple bottom line, incorporating financial profitability, environmental integrity, and corporate social responsibility.” It was removed for this reason. Combining the strategies of breaking down complex competency statement and retaining the ones that were clearly phrased, I generated a list of 191 competency statements. The list of the competency statements is presented in Appendix D. The reduction and simplification of inventory items through this process improved the user-friendliness of the online survey by displaying fewer words, and reduced the cognitive complexity involved in understanding the sentences.

The 16 categories and the number of items under each are listed in Table 3. As shown in the table, some competency categories have more items than the others. There are two causes for a larger number of competency items. Firstly, some competency categories have more items than the others in the ECM model (e.g., the design category). Secondly, some competency categories were combined due to the conceptual overlap (e.g., planning and coordinating category consists of the original planning and organizing, and the scheduling and coordinating).

Table 3. The 16 Categories with Number of Items and Sample Competency Statements

Name of the category	Number of items	Sample of a competency statement
Teamwork	14	Q1_1 Contribute to your team's effort to achieve goals.
Serving clients	14	Q2_4 Provide quick assistance to address a client's concerns.
Creative thinking	9	Q3_3 Integrate seemingly unrelated information to develop creative solutions.
Problem-solving	17	Q4_13 Develop a realistic approach to implementing a chosen solution.
Working with tools and technology	11	Q5_6 Interpret the results obtained from an engineering tool.
Recording and documentation	12	Q6_6 Complete appropriate forms quickly and completely.
Planning and coordinating	16	Q7_6 Use tools to assist with planning (e.g., Gantt charts, precedence diagrams, critical path methods).
Foundations of engineering	10	Q8_5 Integrate engineering knowledge, principles, and concepts to solve engineering problems.
Design	23	Q9_4 Collect data to help with defining a design problem. Q9_13 Review research articles to assist the design process.
Manufacturing, construction and operation	7	Q10_5 Allocate resources to ensure safety and reliability of engineered systems.
Professional ethics	11	Q11_6 Analyze a situation involving multiple conflicting professional and ethical interests.
Quality control and assurance	7	Q12_7 Analyze the impact of quality control on project performance.
Sustainability and societal impact	7	Q13_1 Strive to minimize waste and reduce resource use.
Health, safety, and security in engineering practice	15	Q14_4 Take appropriate steps to address the risks of hazards and unsafe conditions.
Engineering economics	5	Q15_5 Communicate with relevant personnel about project economics, costs, and financial analysis.
Business, legal, and policy	13	Q16_4 Understand market trends in the industry.

Data Collection

Data Collection Strategy

In addition to the 191 self-efficacy questions, the online survey asked the respondents for some demographic information, including gender, degree pursuing, academic level, major, parents' education level (measured through first-generation status), citizenship (categorized in domestic and international), disability status, and veteran status. A few more questions were asked to generate an understanding of the students' experience and engagement with engineering. These questions inquired about the number of experiences students had in the following categories: internships, co-ops, academic engineering projects, extracurricular engineering projects, and non-engineering jobs.

A survey with 191 self-efficacy questions as well as additional questions created a few concerns. First, it was challenging to ensure that respondents answered all the questions. To address this concern, three solutions were implemented: (a) all the self-efficacy questions required an answer; (b) I created a page break and used text to encourage respondents to take a break and finish the survey; (c) in the recruitment email and on the first page of the survey, respondents were reminded that they had a week, and did not have to finish the survey at once. Second, the number of questions was likely to result in survey fatigue for respondents (Ben-Nun, 2008). To reduce survey fatigue without compromising the number of items included, I organized the items into groups according to ECM structure. This created 16 pages of self-efficacy questions, and each page could be finished in a relatively short period of time. The progress of survey completion was displayed in a few ways to encourage the respondents to finish it. The third concern revolved around the content of the competency statements. In the pilot study, a few students provided feedback stating that not all of the competencies seemed relevant to their disciplines. For example, for some students, construction and manufacturing were not taught or mentioned in their curriculum and were not common job duties for some engineering graduates from all majors. To reduce respondents' frustration, they were asked at the end of each group of self-efficacy questions about how much relevance they perceived between the competency statement listed and their field of study/work.

The data collection was done between February and May of 2019. First I retrieved the registrar data for currently enrolled students at the institution of the study. Then using the catalog for university majors as a reference for filtering criteria, I identified the engineering students from all students. The survey was sent out to students at the bachelor's and master's level. Then I de-identified the participants by retaining only their email information and deleting everything else. This list of email addresses for 5562 students was later imported into Qualtrics and used as contact information for survey distribution. An email invitation with a unique survey link for each email address was sent to all participants on the contact list. As an incentive a drawing for a $50 gift card was provided among every 10 participants to encourage participation. After the initial email invitation, a follow-up reminder was sent every two weeks for a month to increase participation.

Overview of the Sample

I collected 445 complete survey responses during the data collection period. Time to complete the survey was between 4 minutes and 1 week. It turned out that over 70% of the respondents (n=328) finished the survey in one pass, where they used 50 minutes or less to complete the survey. One criterion used in the process of data cleaning is checking the standard deviation (Loosveldt & Beullens, 2017). When respondents do not pay attention and provide straight-lining answers that all answers are the same value (e.g., rate 3 for all questions), the standard deviation (SD) tends to be small. As suggested by a statistical consultant, I used $SD<0.20$ as the cutoff for potential straight-lining participants. After downloading all the data, I calculated SD for the answers to all 191 self-efficacy questions. All the questions in the survey were mandatory except the question about entrance in the gift card drawing. In conjunction with checking standard deviation, I also checked the amount of time each participant took to finish the survey. When a respondent spends too little time to answer the survey, there is a chance that the quality of the response is low. All the respondents who took less than 240 seconds to complete the survey with over 200 questions were checked for low-quality answers as well. For example, one participant had a straight-lined answer for each competency group. Using both SD and time for completion as criteria of response quality, I excluded the responses with low completion times and small standard deviations. After the data cleaning process, a sample of 434 responses was ready for the next phase of data analysis.

The majority of the respondents were undergraduate students pursuing a bachelor's degree (n=365), accounting for 84% of the total responses. The master's students (n=69) accounted for 16% of the total responses. Two hundred eighty-two respondents identified themselves as male, and 146 identified themselves as female. Six respondents identified themselves as other gender identities or preferred to not answer the question. The sample also captured a balance of first-generation college students (*n*=48) and non-first-generation college students (*n*=379). Among the respondents, 63 identified themselves as international and 365 identified as domestic. Table 4 shows the number of students by gender, first-generation status, citizenship (international/domestic), and academic level. Although disability status and veteran status data were collected, the number of students who identified in either of the group was less than 10, so these demographic factors were not reported or incorporated in the analysis for this project.

Table 4. Number of Respondents by Gender, First-Generation Status, Citizenship, and Degree Level

	Number of respondents	Percentage
Gender		
Male	282	65
Female	146	34
Parent education		
First-generation	48	11
Non-first generation	379	87
Citizenship		
International	63	15
Domestic	365	84
Degree pursuing		
Bachelor’s	365	84
Master’s	69	16
Grand Total	434	100

Note. Some participants did not identify with the above demographic characteristics in the table. Also, the groups that have a small number of respondents (<10) are not shown in the table.

The respondents represented a variety of engineering disciplines, as shown in Table 5. Among all the participants, strongly represented majors were aeronautics and astronautical, civil, electrical and computer, and mechanical. The majors with fewer than 10 representatives were grouped together in the other engineering majors, including construction engineering, environmental and ecological engineering, materials engineering, nuclear engineering, and interdisciplinary and multidisciplinary engineering. In the bachelor’s group, fourth-year included students reported fourth year and beyond. According to the enrollment data for the surveyed institution (Fall 2018), students with freshman credit hours made up about 18% of the population, students with sophomore credit hours 23%, students with junior credit hours 23%, and students with senior credit hours 36%. In the data collection, students could answer the questions based on their actual year level or credit hour-based year level, so it was hard to align the data exactly. Many students at the surveyed institution came to college with transferred AP credit hours, which may have skewed the enrollment data that was measured by credit hour. The numbers of first-year and fourth-year students were similar, and these two groups have a larger number of respondents compared to the other two academic levels. Overall, the undergraduate students included in this sample resembled the demographic data at the surveyed institution. The ratio between bachelor's and master's participants did not resemble the student enrollment trend at the surveyed institution that the master's students were under surveyed and had a smaller representation in the sample compared to the actual enrollment. However, the distribution across disciplines was not the exact representation of the enrollment. Three underrepresented majors in the sample were chemical, industrial, and mechanical engineering, and one overrepresented major was aeronautics and astronautics engineering.

Table 5. Number of Respondents by Pursuing Degree and Discipline

Major	Bachelor's				Master's		Total
	1st year	2nd year	3rd year	4th year	1st year	2nd year	
Aeronautics and astronautics (AAE)	19	11	14	17	10	15	86
Agricultural and biological (ABE)	5	5	3	8	0	1	22
Biomedical (BME)	5	7	10	9	5	2	38
Chemical (ChE)	12	3	0	1	6	1	23
Civil (CE)	7	7	7	12	8	4	45
Electrical and computer (ECE)	25	28	19	30	1	1	104
Industrial (IE)	6	8	5	4	1	3	27
Mechanical (ME)	26	13	5	8	3	1	56
Other	5	6	4	11	2	5	33
Total	110	88	67	100	35	34	434

As suggested by literature that one's experience is associated with their self-efficacy, I also collected data on respondents' previous engineering experiences. Table 6 shows that among the respondents, many students reported having had no internship experiences (*n*=236) or co-op experiences (*n*=371), which could be due to a large number of first-year and second-year students represented in the sample. The majority of students reported having had experience in one or more academic engineering projects (*n*=402), and many students (*n*=269) had experience with one or more extracurricular engineering projects. Finally, the majority of students reported having had non-engineering job experience (*n*=335). The non-engineering job experience is listed because some summer job or part-time job also provided students with opportunities to develop professional skills, such as communication skills and work ethics.

Table 6. Number of Students with Various Engineering Experiences

Number of experiences	0	1	2	3 or more
Internship	236	112	50	36
Co-op sessions	371	28	10	25
Academic project	32	81	108	213
Extracurricular project	165	133	64	72
Non-engineering job	99	98	111	126

Data Split for EFA and CFA

The data were randomly split in half for the EFA and CFA in the next steps. All the responses were assigned a random number between 1 and 1000 in Excel. Then a sort from small to large split the responses into sample 1 (*n*=217), later used for the EFA, and sample 2 (*n*=217), later used for CFA. After the random split of the sample, I checked the demographics of the two groups to make sure that both groups had equal representation. In both sample 1 and sample 2, the ratio between male and female respondents is close to 2:1. Both samples consist of about 10% of respondents who identified themselves as first-generation college students. The percentage of international respondents is almost identical in both samples as 14%. In both samples, there are about 85% of respondents who were pursuing a Bachelor's degree. The distribution of respondents across disciplines is also very similar between both samples. Table 7 shows that the two samples represent similar populations in terms of degree, discipline, gender, citizenship, and parents' education level. The discipline acronyms are identical with Table 5.

Table 7. Demographics of Random Split Samples

	Sample 1		Sample 2	
	Number of respondents	Percentage	Number of respondents	Percentage
Gender				
Male	145	66.8	137	63.1
Female	68	31.3	78	35.9
Parent education				
First-generation	27	12.4	21	9.7
Non-first generation	185	85.3	194	89.4
Citizenship				
International	32	14.7	31	14.3
Domestic	182	83.9	183	84.3
Degree pursuing				
Bachelor's	185	85.3	180	82.9
Master's	32	14.7	37	17.1
Major				
AAE	37	17.1	49	22.6
ABE	11	5.1	11	5.1
BME	16	7.4	22	10.1
ChE	10	4.6	13	6.0
CE	25	11.5	20	9.2
ECE	59	27.2	45	20.7
IE	12	5.5	15	6.9
ME	30	13.8	26	12.0
Other	17	7.8	16	7.5

Exploratory Factor Analysis

After developing the initial items by using items from ECM and conducting a pilot study to check the wording for easy understanding, I used exploratory factor analysis for two primary purposes. First, exploratory factor analysis provides insight into the latent construct of the scale and the item loading on each factor. Second, using exploratory factor analysis ultimately reduces the number of items (Costello & Osborne, 2005; Netemeyer et al., 2003; Hurley, Scandura, Schriesheim, Brannick, Seers, Vandenberg, & Williams, 1997). There are a few major decisions to make when using EFA to identify the latent structure of self-efficacy in professional engineering competency: (1) sample adequacy, (2) factor extraction and retention, and (3) item retention.

Sample Adequacy

There are different opinions regarding the saturation of the sample for conducting exploratory factor analysis. The ideal sample size is determined by the subject to item ratio, and the suggested subject to item ratio is between 5:1 and 10:1 (Costello & Osborne, 2005). Judging by these criteria, the exploratory factor analysis for 191 variables needs a sample of between 955 and 1910 respondents. In the data collection process, I made multiple efforts to maximize the sample size, such as providing an incentive, increasing the readability of the online survey design, and identifying best times of the week and day to send reminders to potential participants. Due to the challenge of obtaining such a large number of respondents recommended by the aforementioned criteria, I also considered other sample adequacy criteria. I calculated the KMO and Bartlett's test as an indicator to determine the sufficiency of the sample size (Kaiser, 1974; Tobias & Carlson, 1969). According to Kaiser (1974), a KMO above 0.7 is acceptable, between 0.8 and 0.9 is good, and beyond 0.9 is excellent. So my goal was to make sure the KMO was larger than 0.7 for my exploratory factor analysis, which was later tested in the EFA analysis process. The initial KMO for the EFA analysis was 0.75.

Factor Extraction and Retention

There are many options for extraction methods when conducting factor analysis, two of which are commonly used in developing scales (Netemeyer et al., 2003; Worthington & Whittaker, 2006). Two commonly used extraction methods are principal component analysis (PCA) and common factor analysis (FA). PCA is most often used when trying to achieve a parsimonious scale with as few latent constructs as possible but as much original item variance as possible. FA is most often used when trying to find latent constructs for the shared variance among the items. The main difference between PCA and FA is their ability to identify latent factors and theoretical constructs. In this study, I used FA because it aligns better with the purpose of developing a scale (Worthington & Whittaker, 2006). PCA maximizes all variances in the items and analyzes the correlation matrix among the items with those on the main diagonal. When an item has very little variance explained, that item enters the pool to be deleted. FA tries to identify a set of latent variables that could explain the correlation of the items, and it uses the communality estimates of the items on the main diagonal. Using FA for exploratory factor analysis also lays a solid foundation for the confirmatory factor analysis in the next study (Netemeyer et al., 2003).

There are different extraction criteria when using FA for exploratory factor analysis, including principal-axis factoring, maximum likelihood, image factoring, alpha factoring, and unweighted and generalized least squares. In Worthington and Whittaker's (2006) review of scale development, principal-axis factoring (PAF) and maximum likelihood (ML) were the most commonly used extraction methods. Additionally, Netemeyer et al. (2003) suggested in their review of previous work that PAF and ML provide similar results most of the time. Costello and Osborne (2005) indicated that the multivariate normality is a good indicator for choosing between PAF and ML. If the data is relatively normally distributed, ML is a good choice; if the data is not normally distributed, PAF is more statistically sound. In this research, I chose PAF because it provides more robust results with data that are not strictly normal distributed.

A few methods are used to identify potential constructs. The first one is to check eigenvalues. Each component has an eigenvalue that represents the variance explained by that component, and when the eigenvalue is greater than 1, the component could become a potential construct. But a rule of thumb in EFA is that the final structure is decided not only by the correlation matrix but also by the interpretability of the constructs and the items loading on them (Worthington & Whittaker, 2006). After checking the eigenvalues, a scree plot is another useful tool for identifying potential components that can be used together with the eigenvalue. The third method is to use a parallel analysis (PA) to determine the number of factors to retain (O'Connor, 2000). The parallel analysis uses eigenvalues from a random data set with the corresponding number of cases and variables as the baseline to compare with the eigenvalues extracted from factor analysis with the actual data. Factors are retained if the *i*th eigenvalue of the actual data is larger than the *i*th eigenvalue of the random data. In this research, all three methods above were used to provide evidence to justify the decision of factor retention.

Rotating allows better interpretability of the factor loading correlation matrix by presenting the simple structure after rotation (Netemeyer et al., 2003). Common rotating methods are orthogonal and oblique. The former assumes that the factors are not correlated while the latter assumes that some factors correlate to each other. In the workplace and industrial competencies there might be some correlation among factors, so using the oblique rotation method fits well with this study.

Item Retention

It is important to delete unnecessary items not only to help create a parsimonious scale but also to contribute to the decision making of the construct structure. In deciding whether to retain or delete items based on the extraction results and correlation matrix, there are suggested cutoff thresholds to guide this process (Netemeyer et al., 2003; Tabachnik & Fidell, 2001). Netermeyer et al. (2003) suggested looking for items with a factor loading between 0.40 and 0.90 that do not cross-load on more than one factor. In EFA, factor loadings refer to the correlation coefficients between the variables and factors. According to Tabachnick and Fidell (2001), a 10% overlapping variance with other items in the construct is used as a good indicator for retaining an item in the construct. The 10% overlapping variance is reflected through a factor loading of 0.32; thus, any item with a factor loading smaller than 0.32 is deleted. In this project, I used 0.32 as the minimum factor loading to retain an item. Also, when an item loaded on two factors and had a difference smaller than 0.20, I considered the item as cross-loading on two factors and deleted the item.

Each time after I deleted the lowest loading item, I ran a new factor analysis. In this process, a factor with less than three items loading on it is weak and should be carefully evaluated and abandoned. Figure 3 below is a flowchart that represents the iterative process of item retention and deletion decision-making.

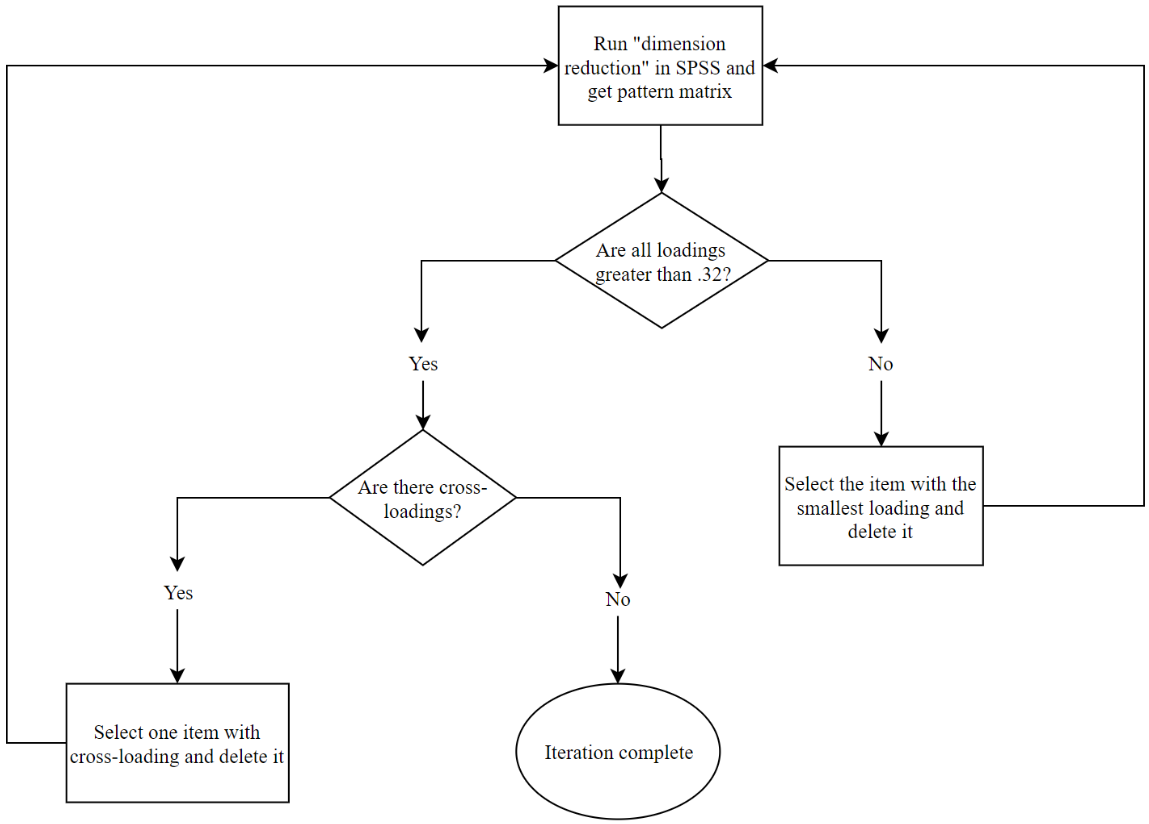

Figure 3. Item Deletion and Retention Decision-Making Process

Confirmatory Factor Analysis

CFA uses Structural Equation Modeling (SEM) as its theoretical foundation (Hooper, Coughlan, & Mullen, 2008). Unlike EFA's exploration nature, a confirmatory structure is specified prior to using CFA. A primary form of CFA is a maximum likelihood estimate. Using maximum likelihood estimation (MLE), the proposed structure is tested regarding its internal consistency and validity. In this research, I used SPSS Amos 25 to conduct CFA.

Convergence and Model Specification

Before conducting CFA, the theoretical structure of the scale is specified from the EFA. The purpose of using CFA is to test the degree of correspondence with the observed covariance among the items. Three major considerations are involved when conducting a CFA (Netemeyer et al., 2003). The first is the interitem correlation and the number of items. A pair of highly correlated items could result in correlated measurement errors in CFA, thus threatening the dimensionality of the scale. MLE uses an iterative process to minimize the observed and implied matrices. When the differences can no longer be reduced further, the convergence occurs.

Nonconvergence sometimes occurs due to common problems such as ill-conditioned data, strong linear correlated items, and model/size complexity. When nonconvergence occurs, the initial model needs to be respecified before being tested again by CFA. A second consideration is the sample size, as CFA is very sensitive to sample size. Generally, CFA requires a large sample size; some researchers have suggested 100 as the minimum while others have suggested 200 (Netemeyer et al., 2003; Hurley, et al., 1997). The third consideration is that CFA not only confirms the structure but can potentially trim some items. CFA can detect highly-correlated items, thus also helping to trim down the scale.

In scale development at the CFA stage, individual item loadings should be statistically significant, and should represent large enough measurement weights. When an item loading is not statistically significant, deleting the item can help increase the model fit. Because factor loadings represent the amount of variance for each item explained by the latent construct, it is important for the factor loadings to be large enough. According to Bogozzi & Yi (1988), the acceptable range for the factor loadings in CFA is between 0.60 and 0.90. A very high factor loading (above 0.9) indicates potential redundancy and results in lower fit values.

Model Fit

When the solution converges, the next step to confirm the structure of a model is to check fit indexes. A popular method to evaluate model fit is to use multiple fit indexes. There are three categories of fit indexes in CFA: absolute fit, incremental fit, and parsimonious fit (Awang, 2012). Chi-square, Goodness-of-Fit Index (GFI) and Root mean square error of approximation (RMSEA) are considered absolute fit indexes. Chi-square assesses overall fit and discrepancies between the covariance matrices and the sample. Suggested good-fit of chi-square is to have *p*-value greater than 0.05. GFI indicates the proportion of variance accounted for by the estimated population covariance. The suggested cutoff for GFI is 0.90 (Joreskog and Sorbom, 1984). Root mean square error of approximation (RMSEA) presents how well the model would fit the covariance matrix by measuring the discrepancy between the hypothesized model, with optimally chosen parameter estimates, and the population covariance matrix (Hooper et al., 2008). RMSEA values close to zero indicate a good fit, and an RMSEA value above 0.08 indicates a poor fit.

There are a few incremental fit indexes, such as the Comparative Fit Index (CFI), that compare the fit of a target model to the fit of an independent (or null) model. CFI is not very sensitive to sample size and the suggested cutoff for CFI is 0.90 (Bentler, 1990). The parsimonious fit is measured by the chi-squared divided by degree of freedom (Marsh & Hocevar, 1985) and the suggested good fit cutoff is to have this index smaller than 3.

When the fitness indices do not demonstrate good fit, some modification of the model is needed. Modification indices (MI) provide evidence of the minimal drop in the chi-square statistic when the corresponding constraint is removed. MI can imply a potential item that needs to be dropped from the model (Hair et al., 2010; Barrett, 2007). MIs that are greater than 3.84 indicate a statistically significant improvement to the model (Hair et al., 2010). For example, when an item estimate has an MI greater than 3.84, deleting the item could improve the fit of the model. When the MI of two errors' covariance is greater than 3.84, adding a covariance between the two errors could improve the model fit. After the modification is made, the scale needs to be tested again using CFA from the first step.

Reliability and validity. In CFA, reliability is measured by composite reliability (CR) that provides evidence for the internal consistency of items in a scale (Formall & Larcker, 1981; Hair, Anderson, Tatham, & Black, 1998). Hair et al. (2010) suggested a threshold of 0.70 for strong evidence of composite reliability. As mentioned in the earlier part of this chapter, criterion-related validity provides an important source of evidence to evaluate a proposed psychometric inventory. Two types of criterion-related validity used in the development of SEIPEC are convergent validity and discriminant validity (Netemeyer et al., 2003).

Convergent validity refers to whether or not independent items within the same construct converge, and could be measured by the correlation of items within a construct. In the CFA process, I used the average variance extracted (AVE) to measure the convergent validity of each factor (Formall & Larcker, 1981). As suggested by Formall and Larcker (1981), the AVE needs to be above 0.50 for each factor within SEIPEC that more than a half of the variance is explained by the model other than the random errors.

Discriminant validity requires that the factors within SEIPEC do not correlate highly with each other, so each factor is measuring a unique sub-construct of SEIPEC. Maximum shared variance (MSV) and average shared variance (ASV) were used to provide evidence for discriminant validity (Fornell & Larcker, 1981). MSV represents the maximum shared variance between one factor and all the other factors, and can be measured by the square of the highest correlation coefficient between latent constructs. ASV is the mean of the squared correlation coefficients between latent constructs. In order to establish strong evidence for discriminant validity, both MSV and ASV should be smaller than the AVE for all the latent constructs for SEIPEC.

One-Way Analysis of Variance

After identifying the factors that contributed to the self-efficacy of professional engineering competency, I calculated each participant's score for each factor. The score is represented by the weighted average (by the CFA factor loadings) of all the items included in each factor. Each respondent had four scores that represented their level of self-efficacy for each factor.

Test of Homogeneity of Variance

In this study, I used SPSS 25 to conduct one-way variance analysis (ANOVA) to test group differences for all identified factors (Agresti & Finlay, 2008). ANOVA allows comparison of means across various groups. It provides a statistical test to evaluate whether the population means for several groups are equal. Because the groups in this study were unequal in size, I first ran a Levene's test to check the homogeneity of the variance (Brown & Forsythe, 1974). When the p-value of the Levene's test is smaller than 0.05, the assumption of homogeneity of variance is violated. When the variance across groups was not equal, I used Welch's test instead of a standard ANOVA when the assumption of homogeneity of variance was violated.

Deciding on the Significant Results

In the ANOVA or Welch's test, I used the p-value to decide whether the difference of the means was significant across groups. When the null hypothesis was rejected across multiple groups, a post hoc test was run if the p-value indicated the statistical significance. Depending on the results of the Levene's test on the equal variance of the group means, a Tukey test or a Tamhane's T2 test was used to determine which means among a set of means differed from the rest (Rafter, Abell, & Braselton, 2002). A Tukey test was used when there were equal variances, and a Tamhane's T2 test was used when the variances were not equal. Also, a Holm-Bonferroni correction was implemented for all the comparisons that showed statistical significance in order to avoid Type I errors (Hommel, 1988). Beyond statistical significance, I also examined the effect size of the mean differences. Hedges' g was used to measure the effect size of the differences when the sample sizes for the two groups are not equal (Hedges, 1981). In the next chapter, I present the results from the exploratory factor analysis, confirmatory factor analysis, and ANOVA.

Limitations of the Research Design

One major limitation for this research design lay in the survey instrumentation and data collection process. The number of items in the initial survey brought two challenges. First, respondents could experience survey fatigue as they went through all the questions in the online survey, which might have caused inattentiveness (Ben-Nun, 2008; Herzog & Bachman, 1981). This inattentiveness might have resulted in a less accurate assessment of the student's self-efficacy towards some competencies. Also, many potential participants turned away from filling out the survey due to the length and time commitment. Although offering a monetary incentive helped to increase participation, it might also have caused selection bias among the participants (Largent, Grady, Miller, & Wertheimer, 2012).

Another caveat of the design was that ECM measures the professional competencies required for engineers; students with little or no prior knowledge of engineering work might not be able to accurately assess their self-efficacy regarding professional engineering competencies. Therefore, research design limitation exists regarding translational validity during the instrumentation process. However, the pilot study that focused on increasing the face validity of survey items helped to increase translational validity by increasing face validity.

RESULTS

In this chapter, I first present the results of the exploratory factor analysis to identify the latent constructs of the self-efficacy for engineering competency inventory, followed by the results of the confirmatory factor analysis. Then I present the difference in self-efficacy in professional engineering competency on the respective latent factors across student subgroups.

Through the exploratory and confirmatory factor analyses, the original survey with 16 categories and 191 items was scaled down to a 20-item inventory measuring four latent constructs. The four latent constructs of self-efficacy for engineering competency include sustainability and societal impact (F1), use of tools and technologies (F2), health and safety (F3), and engineering economics (F4). Each of the constructs is distinct from the others and is measured by a set of unique competency statements. There is some difference in self-efficacy regarding the four constructs by gender and extracurricular experiences. The following subsections in this chapter discuss the results of the analyses in more detail.

Normality Check

Once all the data were collected and cleaned, I checked the normality of the data to prepare for the factor analysis. First, I checked the normality of the data distribution for all 191 items across the 434 complete and valid responses using kurtosis and skewness for univariate normality, because non-normality in the data would violate the assumption of MLE for the CFA (Curran, West, & Finch, 1996; Muthen & Kaplan, 1992). Appendix E includes the tables of skewness and kurtosis for each item for sample 1 (used for EFA) and sample 2 (used for CFA). For the value of skewness in both samples, most of the items fell between -1 and 0. Overall, the data in sample 1 and sample 2 were considered to follow the normal distribution, as there was no kurtosis above 7.0 or skewness above 2.0 (Curran et al., 1996; Muthen & Kaplan, 1992). I did not check the multivariate normality due to the large number of variables involved.

Next a correlation analysis was performed to examine whether the 16 categories were highly correlated. Because a correlation matrix of 191 items would have been hard to perform, I first calculated the mean for each category and created 16 new scores for each sample as a proxy to their answers. Using the 16 new scores for each respondent, I ran a correlation check to see whether any of the categories were highly correlated. I used a cutoff criterion of 0.71, where the squared of the correlation was smaller than 0.5, indicating that the two categories were not highly correlated with each other. All the correlation coefficients were below 0.71, indicating that there was no strong correlation between any two categories.

EFA Results

Factor Extraction and Item Retention

Following Pohlmann's (2004) suggestion to collect enough data and then randomly split the data in half for EFA and CFA, 217 responses (sample 1) were used to perform the exploratory factor analysis and the other half (sample 2) were saved for the confirmatory factor analysis done later. Using the dimension reduction function from SPSS 25, my first attempt to identify the latent constructs with principal factor axis as the factor extraction method and direct oblimin as the rotation method provided a solution of 31 latent constructs with eigenvalues greater than 1. After checking the scree plot, identifying the elbow point, and using parallel analysis, a 5-factor model provided the most interpretable solution. In this initial exploratory factor analysis, KMO was 0.75. The 5-factor model explains 43.2% of the variance. Following an iterative item deletion process (Worthington & Whittaker, 2006), I deleted low-loading items (smaller than 0.32) and cross-loading items (cross-loading difference smaller than 0.20).

Table 8 shows the factor loadings and item communalities of the exploratory factor analysis. In the final results of the EFA after the iterative process, the variance explained by the model increased from 43.2% to 51.9% and the KMO increased from 0.75 to 0.90. Fifty-six items were retained and loaded across five factors. All the remaining items had a factor loading with no cross-loadings, ranging from 0.42 to 0.86. I also examined the common variance explained by each item through communalities. The communalities ranged from 0.28 to 0.69. Costello and Osborne (2005) suggested that the range of communalities in social science is between 0.40 and 0.70. In these EFA results, the lower communalities (below 0.40) were from the items within the fifth factor (collaboration and communication). In the later CFA analysis, the lower communality items were examined further for the model fit.

The EFA results presented a model of five latent constructs that contributed to self-efficacy for professional engineering competency. Across the five factors, the factor loadings for all items were above 0.40, with no concerning cross-loading. Factor 1 captured the sustainability and societal impact issue in engineering and had 12 items. Factor 2 captured the use of tools and technologies in engineering and had 12 items. Factor 3 captured engineering economics and had

5 items. Factor 4 captured the health and safety issues in engineering and had 10 items. Factor 5 captured the coordination and collaboration issues in engineering practice and had 16 items. By comparing these remaining items with the ECM model and judging the items left in each of the five factors, a temporary name was assigned to each of the emerging latent constructs. The five factors are F1: Sustainability and societal impact, F2: Use of tools and technologies, F3: Engineering economics, F4: Health and safety, F5: Coordination and collaboration.

Table 8. Factor Loadings and Commonalities of the Exploratory Factor Analysis

Items	Factor					Communality
	F1	F2	F3	F4	F5	
Q13_2 = Understand the environmental effects of a product at every stage of its existence.	.79					.67
Q13_4 = Ensure equipment and systems are designed to minimize environmental impact.	.71					.68
Q8_7 = Evaluate societal/cultural perspectives in the development of a current project.	.71					.51
Q13_3 = Safeguard the public interest.	.67					.56
Q9_16 = Assess environmental impact when designing.	.66					.53
Q8_8 = Identify the potential contribution of emerging technology to the public good.	.66					.44
Q13_7 = Deliver presentations to the public regarding the social and environmental impacts of a project.	.58					.50
Q13_1 = Strive to minimize waste and reduce resource use.	.58					.48
Q8_9 = Compare the technical and nontechnical features of alternative courses of action.	.57					.49
Q9_15 = Identify the impact of an engineering design to the public health, safety, and welfare.	.57					.44
Q13_6 = Analyze the impacts of a project on diverse stakeholders.	.56					.41
Q8_6 = Consider public input when exploring technical possibilities.	.55					.42

Table 8. (continued)

Items	Factor					Communality
	F1	F2	F3	F4	F5	
Q5_3 = Apply selected tools (or technological solutions) to the tasks at hand.		.81				.59
Q5_1 = Identify potential tools (e.g., hardware and software) appropriate to the task at hand.		.78				.57
Q5_9 = Maintain engineering tools and equipment.		.76				.51
Q5_8 = Learn to maintain and troubleshoot tools and technologies.		.76				.52
Q5_10 = Take the appropriate corrective action when identifying causes of error for a tool.		.73				.58
Q5_7 = Learn to apply a new or updated tool to solve an engineering problem.		.67				.53
Q5_6 = Interpret the results obtained from an engineering tool.		.63				.54
Q5_4 = Operate tools in accordance with operating procedures and safety standards.		.58				.48
Q5_5 = Identify potential risks related to the use of tools and equipment.		.56				.38
Q5_11 = Develop alternatives to complete a task if a desired tool is not available.		.55				.48
Q9_11 = Use software related to your engineering discipline.		.55				.33
Q9_21 = Apply prototyping methods to the design process.		.48				.37
Q15_2 = Calculate the financial indicators of a project.			.86			.72
Q15_4 = Conduct comparative cost analysis on various designs of a project or product.			.84			.66
Q15_3 = Recognize the potential economic risks associated with a project or product.			.80			.69
Q15_5 = Communicate with relevant personnel about project economics, costs, and financial analysis.			.72			.62
Q15_1 = Estimate the cost of a project, product, or process.			.70			.59

Table 8. (continued)

Items	Factor F1	F2	F3	F4	F5	Communality
Q14_5 = Follow organizational protocols for workplace emergencies.				.75		.63
Q14_1 = Take precautions to prevent work-related injuries and illness.				.73		.61
Q14_12 = Report injuries, incidents, and workplace hazards to a supervisor.				.72		.54
Q14_2 = Comply with federal, state, local, and environmental regulations, as well as company health and safety policies.				.72		.60
Q14_9 = Use equipment and tools safely.				.71		.56
Q14_6 = Maintain a sanitary and clutter-free work environment.				.67		.45
Q14_4 = Take appropriate steps to address the risks of hazards and unsafe conditions.				.66		.65
Q14_13 = Contribute to the discussion of safety concerns in the workplace.				.63		.59
Q14_7 = Properly handle and dispose of hazardous materials.				.60		.52
Q14_11 = Understand the legal rights of workers regarding workplace safety and protection from hazards.				.56		.48
Q1_1 = Contribute to your team's effort to achieve goals.					.72	.36
Q6_7 = Forward forms to the appropriate personnel in a timely manner.					.62	.40
Q2_11 = Develop a cooperative working relationship with a client.					.61	.39
Q6_8 = Prioritize tasks that require immediate attention.					.60	.38
Q2_10 = Be professional when working with a client.					.60	.31
Q2_8 = Adjust proposed solutions based on a client's feedback.					.57	.34
Q7_1 = Formulate effective strategies to complete a project.					.56	.37
Q7_12 = Effectively execute the tasks according to their urgency and importance.					.54	.43
Q2_14 = Communicate promptly with clients about the decisions that affect them.					.53	.35

Table 8. (continued)

Items	Factor					Communality
	F1	F2	F3	F4	F5	
Q6_6 = Complete appropriate forms quickly and completely.					.51	.40
Q7_11 = Prioritize multiple competing tasks.					.50	.38
Q1_3 = Serve as either leader or follower depending on the need of the team.					.50	.29
Q2_2 = Ask clarifying questions to understand a client's needs.					.49	.28
Q4_6 = Formulate plans for preventing the same problem from reoccurring after solving a problem.					.48	.34
Q7_8 = Keep track of details to ensure work is performed accurately and completely.					.47	.37
Q6_11 = Make notes on important changes when updating documents.					.42	.42

Factor Distinction and Reliability Analysis

By the end of the item elimination process, I retained the 5-factor model that was consistent as the initial results of the exploratory factor analysis. The five latent constructs that contribute to engineering students' self-efficacy towards professional skills are (a) sustainability and societal impact, (b) use of tools and technologies, (c) engineering economics, (d) health and safety, and (e) coordination and collaboration. These constructs match the original ECM across "sustainability and societal impact," "engineering foundation," and "design" for factor 1; "use tools" and "design" for factor 2; "engineering economics" for factor 3; "health and safety" for factor 4; and a combination of "teamwork," "client serving," "creative thinking," "problem-solving," "process of documentation," and "coordinating and planning" for factor 5. A reliability test was performed using Cronbach's α (Cronbach, 1951). The Cronbach's α for the scale was 0.955, indicating strong reliability.

Furthermore, I explored the discriminant validity of the five factors. The correlations across the five identified factors are shown in Table 9. The correlations across the five factors are smaller than 0.50, indicating that the five constructs are not highly correlated but distinct from each other (Worthington & Whittaker, 2006).

Table 9. Factor Correlations from the Exploratory Factor Analysis

Latent factor	1	2	3	4	5
1- Sustainability and societal impact	-	.36	-.35	.38	.38
2- Use of tools and technologies		-	-.29	.23	.46
3- Engineering economics			-	-.22	-.22
4- Health and safety				-	.37
5- Coordination and collaboration					-

CFA Results

The CFA was conducted using SPSS Amos 25. I used the other half of the data (n=217) to conduct a CFA to confirm the five-factor structure found in EFA. Initially adopting the latent constructs and the loading items, I tested the fit of the model by inspecting parameter estimates, checking the multiple goodness-of-fit indexes, and identifying modifications to increase model fit (Schreiber et al., 2006; Khan, 2006; Klein, 1998). After testing the initial 5-factor model from the EFA results, I found that the factor of collaboration and coordination had low communalities from items that also suffered from low factor loadings of its items, low component reliability, and low average variance extracted, indicating that including this factor would compromise the consistency between the model and the data.

Then a modified model of 4-factor was tested. Judging by the increasing fit indexes (e.g., GFI, CFI, TLI, RMSEA), the 4-factor model fit better than the 5-factor model. In this process items with item reliability smaller than 0.4 were deleted, which is a standardized factor loading smaller than 0.62 (Awang, 2012). After deleting an item with smaller loading, a new analysis was run with the adjusted model. This iteration process led to a final model with acceptable factor loadings and fit indexes, resulting in 20 items left from the original 56 items from the EFA results.

The chi-square was 233.64 with 161 degrees of freedom. $p<0.001$ suggests that the specified model may not be better fitting than a baseline model; thus this fit index of chi-square cannot be used as evidence to support the model fit. As some researchers advocate (Schlermelleh-Engel et al., 2003; Vandenberg, 2006), chi-square is not relied upon as a basis for the acceptance or rejection of a model, so I also checked other fit indexes. Other fit indexes fit all the recommended cutoffs to indicate that the model was able to explain the data used in the CFA analysis (Hu & Bentler, 1995; Awang, 2012). Specifically, the RMSEA was 0.04, GFI was 0.904, CFI was 0.969, and TLI was 0.963, all suggesting that the model was adequate to explain the data collected. The goodness-of-fit index for the final model is presented in Table 10. In the final CFA model, there are 20 items loaded on four factors that measure the self-efficacy of professional engineering competency. The four final constructs are sustainability and societal impact (5 items), use of tools and technologies (5 items), engineering economics (5 items), and health and safety (5 items).

Table 3. Fit Indexes of the Model Obtained from Confirmatory Factor Analysis

Fit index	
Chi-square	233.64
df	161
p	< 0.001
RMSEA	0.046
GFI	0.904
CFI	0.969
TLI	0.963
Number of factors	4
Total number of items	20
Factor (number of items)	F1 (5 items)
	F2 (5 items)
	F3 (5 items)
	F4 (5 items)

All four average variance extracted were above 0.50, showing that the variance captured by the constructs was greater than the amount of variance due to measurement error (Hair, Black, Babin, & Anderson, 2010). The discriminant validity was measured by comparing maximum shared variance (MSV) and average variance extracted (AVE) (Fornell & Larcker, 1981). MSV for the four factors was 0.31 for F1, 0.14 for F2, 0.17 for F3, and 0.31 for F4. All four MSV values were smaller than the respective AVE values, suggesting that the factors are discriminant from each other. Figure 4 shows the factor matrix for the final model, and Table 11 shows the correlation efficient for the four factors. All four factors in the final model are distinct from each other, and have distinct items loading on each of them.

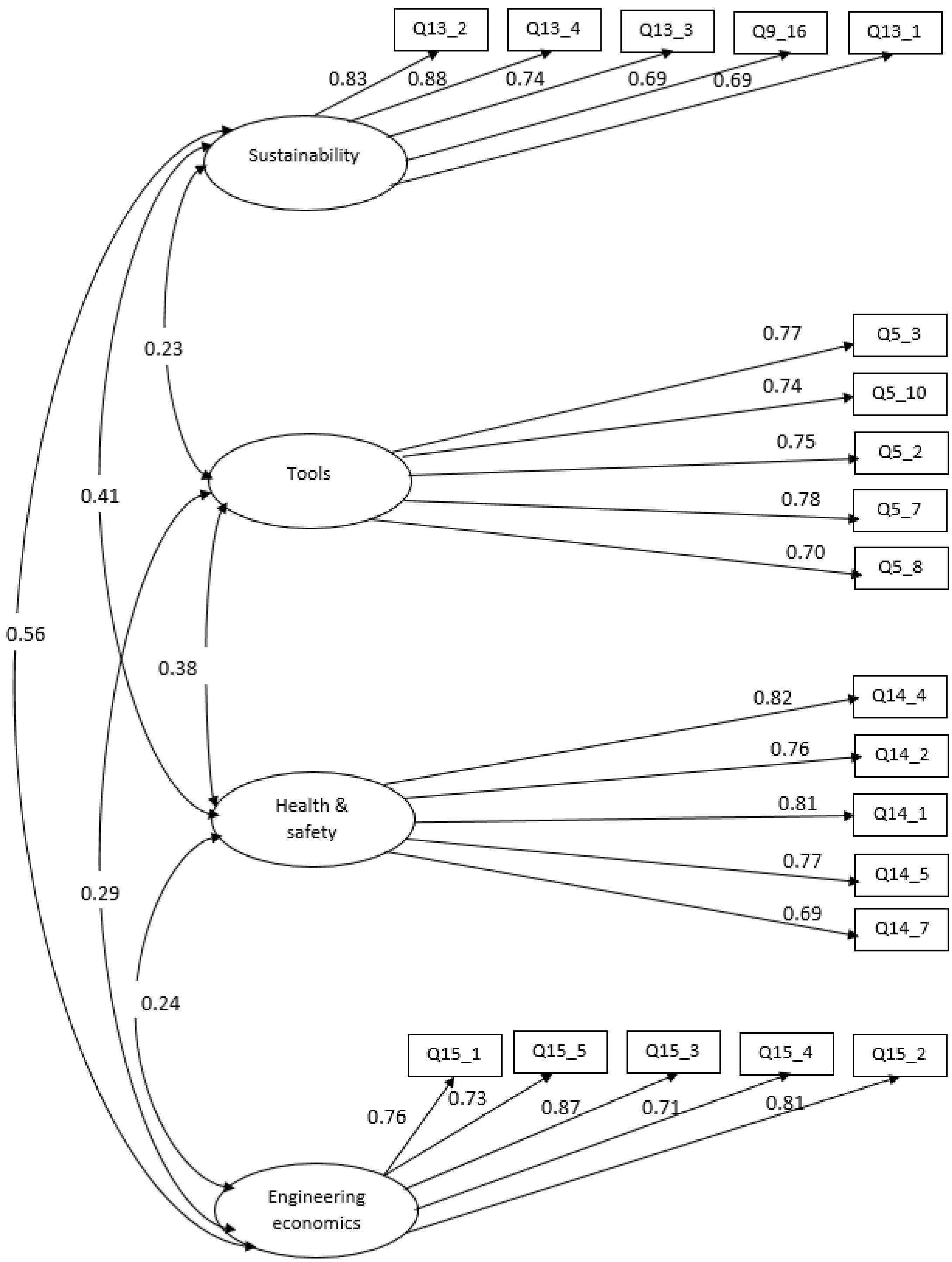

Figure 4. Model of Resulting Confirmatory Factor Analysis

Table 4. Correlation among the Four Factors

Factor	1	2	3	4
1- Sustainability and society impact	-	.23 **	.41 ***	.56 ***
2- Use of tools and technology		-	.38 ***	.29 ***
3- Health and safety			-	.24 **
4- Engineering economics				-

**p*<0.05, ***p*<0.01, ****p*<0.001

Table 12 shows the factor loadings and reliability estimates for confirmatory factor analysis. The standardized factor loadings explain the correlation between an item and its corresponding factor. All factor loadings for the 20 items were above 0.60, and the item reliabilities were above 0.40. All construct reliability for the four factors were above 0.70, showing good internal consistency.

Table 5. Factor Loadings and Reliability Estimates for Confirmatory Factor Analysis

Variable		Standardized factor loading	*SE*	Item reliability (R^2)	Construct reliability	Average variance extracted
Latent factor	Indicator					
Sustainability and societal impact					.88	.59
Q13_2 = Understand the environmental effects of a product at every stage of its existence.		.83	.06	.69		
Q13_4 = Ensure equipment and systems are designed to minimize environmental impact.		.88	.06	.78		
Q13_3 = Safeguard the public interest.		.74	.06	.54		
Q9_16 = Assess environmental impact when designing.		.69	.07	.48		
Q13_1 = Strive to minimize waste and reduce resource use.		.69	.06	.48		
Use of tools and technologies					.87	.55
Q5_3 = Apply selected tools (or technological solutions) to the tasks at hand.		.75	.06	.57		
Q5_10 = Take the appropriate corrective action when identifying causes of error for a tool.		.74	.06	.54		

Table 12. (continued)

Variable: Latent factor / Indicator	Standardized factor loading	Standard error	Item reliability (R^2)	Construct reliability	Average variance extracted
Q5_7 = Learn to apply a new or updated tool to solve an engineering problem.	.78	.06	.60		
Q5_8 = Learn to maintain and troubleshoot tools and technologies.	.70	.07	.49		
Health and safety				.90	.60
Q14_4 = Take appropriate steps to address the risks of hazards and unsafe conditions.	.82	.05	.68		
Q14_2 = Comply with federal, state, local, and environmental regulations, as well as company health and safety policies.	.76	.05	.58		
Q14_1 = Take precautions to prevent work-related injuries and illness.	.81	.05	.65		
Q14_5 = Follow organizational protocols for workplace emergencies.	.77	.05	.59		
Q14_7 = Properly handle and dispose of hazardous materials.	.69	.06	.48		
Engineering economics				.87	.60
Q15_1 = Estimate the cost of a project, product, or process.	.76	.06	.58		
Q15_5 = Communicate with relevant personnel about project economics, costs, and financial analysis.	.73	.06	.54		
Q15_3 = Recognize the potential economic risks associated with a project or product.	.87	.07	.75		
Q15_4 = Conduct comparative cost analysis on various designs of a project or product.	.71	.07	.50		
Q15_2 = Calculate the financial indicators of a project.	.81	.07	.65		

The CFA results suggested retaining four of the five factors from EFA—sustainability and societal impact (F1), use of tools and technologies (F2), health and safety (F3), and engineering economics (F4). Further explanation of the 20 items that emerged to measure the four latent factors of self-efficacy in professional engineering competency is provided below.

Factor 1: Sustainability and Societal Impact

Five items in the final model fall under the latent factor of sustainability and societal impact. Q13_2, Q13_4, and Q9_16 explicitly call out the importance of understanding, assessing, and implementing environmental impact in the product development process. Q13_1 emphasizes minimizing waste to reduce the use of resources, which falls under overall environmental consideration when designing engineering solutions. Q13_3 calls out safeguarding the public interest, tying into the societal impact component.

Factor 2: Use of Tools and Technologies

The use of tools and technologies focuses on three areas: selecting and applying appropriate tools for the task at hand, learning continuously and updating one's knowledge about tools and technologies, and maintaining and troubleshooting regarding tools and technologies.

Factor 3: Health and Safety

The five items in this category described competencies in awareness about following government and organization rules and regulations, as well as specific action-oriented competencies in "handling hazardous material," "addressing the risk of hazards and unsafe conditions," and "preventing work-related injury and illness."

Factor 4: Engineering Economics

The items in engineering economics include five competency statements about understanding the economic and financial aspects of a project. These competencies require engineers to keep the financial implications of a project or product in mind at various stages. Engineering economics is the application of economics techniques to the evaluation of design and engineering alternatives (Sullivan, Bontadelli, & Wicks, 2001). It is offered as an economics course in engineering programs.

ANOVA

Table 13 shows the mean and standard deviations of the respondents' weighted scores for each factor. As mentioned in the method section, the scores were calculated as the weighted average of the five items under each factor, where I used the standardized factor loadings from CFA as the weight.

Table 6. Descriptive Statistic of Self-efficacy in the Four Latent Constructs of Professional Engineering Competency

	N	*Min*	*Max*	*M*	*SD*
Society	434	1.00	5.00	3.56	.86
Tool	434	1.00	5.00	3.78	.74
Safety	434	1.00	5.00	4.06	.77
Economics	434	1.00	5.00	3.27	.92

Using SPSS 25, I performed ANOVA analysis to compare the mean difference across groups. Table 14 shows the self-efficacy scores for the whole sample across four latent factors. Through this process, I identified gender differences for F2 (use of tools and technologies) and F4 (engineering economics). I also found that respondents with different numbers of extracurricular experiences showed different levels of self-efficacy regarding F2. In this chapter I am only reporting group differences that are statistically significant. A full list of ANOVA result tables is included in Appendix F.

Gender

After calculating the homogeneity of variances, I found that the equal variances assumption was supported for the scores of all four factors. ANOVA was conducted to compare the mean scores of all four factors between male and female. A significant difference was found between male and female respondents' answers for the use of technology and tools (F2) and engineering economics (F4). A *p*-value smaller than 0.001 indicated the significance of the observed difference. Table 14 shows the results of the differences between male and female students.

Male respondents had a mean of 3.90 in their self-efficacy for the use of tools and technologies competencies. Female respondents had a mean of 3.56 in their self-efficacy for the use of tools and technologies competencies. The difference between the two groups for self-efficacy in the use of tools and technologies was 0.34. Using Hedges' *g* for effect size calculation for groups with different sample sizes (Hedges, 1981), a measure of 0.45 indicated a small to medium effect size for this difference between the two groups. Male respondents rated themselves higher in their competencies in using tools and technologies compared to female respondents.

Male respondents had a mean of 3.38 for their self-efficacy in the engineering economics competencies. Female respondents had a mean of 3.04 for their self-efficacy in engineering economics competencies. The difference between the two groups for self-efficacy in the use of tools and technologies was 0.34. The Hedges' *g* for effect size was 0.37 between male and female respondents, indicating a small to medium effect size for this difference between the two groups. Male respondents reported higher levels of self-efficacy in their competencies in engineering economics than female respondents.

Table 7. Differences in Self-Efficacy for the Use of Tools and Technologies and in Engineering Economics between Male and Female Students

	Male (n=282)	Female (n=146)	Mean difference	Hedges' g	p
	M (SD)	*M (SD)*			
F2	3.90 (0.70)	3.56 (0.78)	0.34	0.45	***
F4	3.38 (0.89)	3.04 (0.94)	0.34	0.37	***

*** p<0.001

Engineering Extracurricular Projects

After calculating the homogeneity of variances, I found that the equal variances assumption was supported for the scores of all four factors. ANOVA was conducted to compare the mean scores of all four factors across groups. A significant difference in the use of technology and tools (F2) was found between respondents who had no extracurricular engineering projects and those who had three or more extracurricular engineering project experiences. The difference was found to be statistically significant (p<0.001) after the Holm-Bonferroni correction.

Respondents with no extracurricular engineering project experiences had a mean of 3.63 for their self-efficacy in the use of tools and technologies competencies. Respondents with three or more extracurricular engineering projects experiences had a mean of 4.04 for their self-efficacy in the use of tools and technologies. The difference between the two groups for self-efficacy in the use of tools and technologies was -0.41. A result of 0.52 of the Hedges' *g* indicated a medium effect size for this difference between the two groups. Students with more extracurricular engineering experiences reported higher levels of self-efficacy in their competencies in using tools and technologies to solve engineering problems.

DISCUSSION

This research aimed to explore and confirm the factors that contribute to the self-efficacy of engineering students for professional engineering competencies. Through the process of a pilot study, exploratory factor analysis, and confirmatory factor analysis, four factors were identified from among the 191 ECM professional engineering competency items. The four factors have corresponding categories within the ECM and were named accordingly: sustainability and societal impact, use of tools and technologies, health and safety, and engineering economics. The emergence of the four factors through this process indicates that these four latent constructs captured the most variance across the respondents in this sample, which included 434 engineering students across all year levels pursuing a bachelor's or master's degree.

In this initial development of SEIPEC, there were two important findings. The first important finding is the emergence of the four factors and the disappearance of the other competency groups, which is shown in the final SEIPEC model and the 20 items identified. The second important finding is the level of perceived self-efficacy by the respondents in this project.

In this chapter, I discuss the following topics: (a) the emergence of the four factors and the elimination of the others from ECM; (b) group differences in the factors between male and female, and between students with different numbers of extracurricular engineering projects; (c) limitations of the research method and design; (d) future work; and (e) implications and suggestions.

The Emergence of the Four Factors

In the EFA process, the principal axis factoring extraction method was used to identify unique factors that explain the group differences. The five factors that showed up captured the latent constructs that explained the differences in students' self-efficacy towards professional engineering competencies measured by the 191 items. For example, students varied enough in their answers with regard to how much confidence they have in their sustainability and societal impact competencies. Some students were confident while some students were not confident in their ability to assess environmental and societal impact. Those items that were removed during the process did not explain the differences, meaning that there was significant homogeneity in students' answers to these questions. The emergence and disappearance of certain competencies reflect previous research findings that professional competencies are challenging to teach in a traditional classroom setting (Shuman et al., 2005; Walter & Radcliffe, 2007). The following discussion reveals how all four factors identified for SEIPEC are consistent with the ABET student outcomes.

CFA results provide a snapshot of perceived professional engineering competency by the student population. The four distinct factors identified among all the competencies were (a) sustainability and societal impact, (b) use of tools and technologies, (c) health and safety, and (d) engineering economics. As discussed earlier in this chapter, many competencies such as teamwork, problem-solving, creative thinking, coordinating and planning, engineering foundations, and others were not identified by students as distinct factors. However, students will not necessary accomplish the tasks in the SEIPEC unless they collaborate with others (teamwork), identify and solve problems (problem-solving), and understand and apply engineering knowledge (engineering foundation).

Unlike previous self-efficacy inventories in engineering (e.g. Engineering Self-efficacy Scales, Mamaril, 2014; LAESE, Marra & Bogue, 2006), SEIPEC measures professional competencies instead of constructs related to engineering learning. In Engineering Self-efficacy Scales, the three latent constructs are design, tinker, and experiment, all of which focus on the engineering activities associated with the learning process. In LAESE, the questions on self-efficacy are focused on academic learning experience and outcome expectations. Meanwhile, WS-Ei measured self-efficacy in workplace competencies in areas like learning, problem-solving, pressure, teamwork, role expectation, sensitivity, and work politics, so there is no overlap between WS-Ei and SEIPEC on the latent constructs either. The emerging four factors are more specific to the engineering workplace compared to the other competencies, which could be either generic professional skills or more academic skills (engineering foundation). Yet without further investigation of students' perceptions of professional competencies, it is hard to draw conclusions about why the four factors emerged as latent factors for self-efficacy in professional engineering competency.

Among the four factors, there is a natural connection between two factors (F2 and F3) and engineering courses. Teaching students about engineering tools and on topics of health and safety is often handled in labs and other hands-on projects. Due to the history of engineering work, both F2 and F3 are critical components associated with the nature of engineering. But it was less intuitive to see the emergence of F1 (sustainability and societal impact) and F4 (engineering economics). Although identified as a student outcome in ABET, it is less clear how programs teach students competency in considering sustainability and societal impact in their engineering practices, and whether the intentional curriculum design is consistent across engineering programs (Kuo & Jackson, 2014). After examining plans of studies for many undergraduate engineering programs, I found that besides industrial engineering and civil engineering, engineering economics (F4) is not a core curriculum requirement for many engineering disciplines in the surveyed institution. This could contribute to the emergence of engineering economics as a distinct latent factor.

Training and emphasis on health and safety may vary from discipline to discipline, and from school to school (Wilbanks, 2015). Some engineering programs successfully integrate students' competency training in health and safety into their curriculum (Wilbanks, 2015). These programs require students to take courses pertaining to health and safety, in which they are expected to demonstrate competence in various system safety analysis methods and apply them to real-world situations (Wilbanks, 2015). The teaching of health and safety at the surveyed institution is offered outside of the College of Engineering in the program of occupational health science. Though it is likely that students receive some health and safety training and education in labs, there is not much literature on teaching health and safety training in engineering education, and more information about how health and safety is taught in engineering programs across all institutions is needed.

As engineering and business are often both significant units in many corporate practices and inform each other's decisions (Passow, 2012), it makes sense that engineering students realize that engineering economics is not just for business students and professionals but could also benefit professional engineers' practices. Historically, a balance between engineering and business facilitated the development of engineering societies in the United States (Layton, 1971).

Engineering economics is the application of economics techniques to the evaluation of design and engineering alternatives, and it is considered as a key competency for engineers to perform successful engineering design and problem-solving (Zoghi, 2015). It is offered as an economics course in engineering programs. In the institution surveyed for this research, engineering economics is offered as a required course only in Industrial Engineering. There are a limited number of previous studies on the teaching and assessment of engineering economics in the realm of engineering education since 2000. Studies after 2000 emphasize the importance of teaching engineering economics and show various approaches to combining engineering economics learning with problem-solving (e.g., Ryan, 2004; Zoghi, 2015). Studies prior to 2000 called for more research on teaching engineering economics (e.g., Lavelle, Needy & Umphred, 1997).

Besides the four factors that emerged from the analysis results, many items were removed. As shown in the Methods section, there were 191 competency statements across 16 categories before the exploratory and confirmatory factor analysis. Of all the 16 categories, only four were represented in the final results, and many competency groups were removed. Among the categories removed were ABET outcome-related competencies such as teamwork, problem-solving, coordinating and planning, and engineering ethics. In the final scale, the teamwork and coordinating and planning competencies were not represented by any items. While competencies for problem-solving, design, ethics, communication, and coordinating were reflected in the four existing factors, they did not emerge as individual factors.

Because the factor analysis process only identified the latent factors that contribute to understanding variances within the group, competency groups that were removed did not explain the variance, indicating that students were reporting homogenous levels of self-efficacy for these competencies. One surprise in the development of SEIPEC was the absence of communication and teamwork as latent factors to explain self-efficacy for professional engineering competency. Numerous studies of workplace competency for engineers and other professionals indicate that these are key competencies for professionals in the workplace (Passow & Passow, 2017; Baytiyeh & Naja, 2011; Passow, 2012).

There may be a few reasons that certain competency groups did not show up as distinct factors for self-efficacy towards professional engineering competencies, but I was not able to explain the disappearance of the communication and teamwork related competencies.

First, although teamwork and communication skills are assessed in some engineering courses (e.g., Ohland, Loughry, Woehr, Bullard, Felder, Finelli,…& Schmucker, 2012), students who lack exposure to the workplace might fail to realize the connection between effective communication and career success (Dunsmore, Turns, & Yellin, 2011). Teaching these competencies and helping students to understand their importance requires instructors to call out and explain why these competencies can help students to be successful in school and future work (Walther & Radcliffe, 2007). Students might know that these are important learning outcomes, but without experiencing professional life in engineering it is hard for them to foresee the importance of these professional skills. Many of the students in the sample had no internship or co-op experiences, which offer important professional development opportunities for students to acquire an understanding of the professional workplace. The curriculum setup will inform students about the importance of learning certain engineering tools, which is unique engineering training that students might not get the chance to develop elsewhere. However, competencies like teamwork and communications are common skills in everyday life for many students, and thus less likely to be perceived as professional competencies required for engineers.

Second, self-assessment has been critiqued for its lack of accuracy (Dunning, Heath, & Suls, 2004; Falchikov & Boud, 1989; Brown, Andrade, & Chen, 2015). Previous research on inflated self-assessment (Dunning & Kruger, 1999) indicates that people tend to overrate their competency. More recent studies indicate that people are capable of assessing their ability accurately, although novices normally assess themselves less accurately than experts do (Nuhfer et al., 2017). Because many of the respondents were students with no internship or co-op experiences, they can be seen as novices and might have provided less accurate self-assessment. Impacted by the potential inaccuracy caused by self-assessment, the results could pick up variances that were caused by skewed self-assessment.

Third, social desirability is a common limitation in self-assessment; respondents give themselves a higher score in some pro-social factors in order to conform to social norms (Paulhus, 1991; Callegaro, 2008). In the data collection process for SEIPEC, some students scored themselves higher on the competency statements that were promoted as important skills by their professors and programs. Due to this tendency, bias might exist for higher self-efficacy ratings in certain categories of competencies (e.g., ethics).

Finally, another explanation for the absence of collaboration as a unique factor in the results is the fact that the competency statements were not relatable to engineering students. The students did not interpret the competency statements in a certain category as professional competencies. Even though students in the pilot study helped to improve the clarity of the competency statements, I might have failed to present the competencies in the most suitable way.

Group Differences in the Four Factors

Among all the means comparison analysis, significant differences among groups were identified with gender and number of extracurricular engineering experiences. Male students were found to rate their self-efficacy higher than their female counterparts in the use of tools and technologies and in engineering economics. As a limitation for this research, I cannot conclude if the difference is the true difference for the compared groups or if the difference results in how students' interpreted the measurement items (i.e., a potential bias in the SEIPEC instrument).

Gender

Gender differences were observed in the average self-efficacy scores for F2 (tools) and F4 (economics); female respondents had lower self-efficacy ratings than their male counterparts. In particular, the effect size of the difference in self-efficacy between male and female students was 0.45 for F2 (use of tools and technologies).

Overall, the field of engineering has long suffered from a gender imbalance at every stage along career paths, demonstrated by a lack of female engineering students in college and a lack of female engineers in the workplace (Yoder, 2017). Considerable research has been conducted to study gender differences in engineering with regard to female students' experiences, work experiences for female professional engineers, and the choice of engineering as a college discipline and career path (e.g. Marra et al., 2009; Singh, Fouad, Fitzpatrick, Liu, Cappaert, & Figuereido, 2013; Lent et al., 2003). Many of the studies show that female students' experiences are quite different from those of their male counterparts, especially in self-assessment and perceived belonging (Marra et al., 2009; Meyers et al., 2012). The findings from this research are considered to be aligned with previous research findings in showing that female students might have lower self-efficacy in some aspects compared to their male counterparts (e.g., use of tools and technologies, and engineering economics), or there is no difference observed in self-efficacy (e.g., sustainability and societal impact, and health and safety)

Furthermore, in previous studies on retention of female engineering students and female engineers, many cultural and value-related factors were found to be relevant to individuals' reasons for leaving (Singh et al., 2013; Wang et al., 2013). Wang et al. (2013) found that many female engineering students with strong potential to succeed in engineering might move to other majors due to the mismatch between personal values and the values of an academic discipline. Female students are more likely to express a desire to interact with others in the workplace and provide direct help to teammates (Wang & Degol, 2013). The dropout of collaboration and coordination competencies from the development of the SEIPEC reaffirmed the fact that this group of competencies was not seen as a part of professional engineering competency.

Extracurricular Engineering Projects

Extracurricular experiences are activities that students participate in outside of the required curriculum and are considered a form of high-impact experiential learning activities in higher education (Kuh, 2008). Previous research has found that participation in extracurricular activities facilitates students' development of skills such as leadership, analytical skills, and more (Ro & Knight, 2016). In the current study, students who participated in three or more extracurricular engineering projects reported "much confidence" in their ability to use tools and technologies (*mean*=4.04), compared to those who never participated in any extracurricular engineering projects (*mean*=3.63). The ANOVA results for the two groups (three or more versus no extracurricular engineering projects) also support the concept that participation in extracurricular engineering projects correlates with higher levels of students' self-efficacy in competencies for using tools and technologies to solve problems. A reasonable assumption is that students gain engineering experience as they participate in engineering extracurricular activities, where mastery experience is a source of self-efficacy.

Limitations of the results

The strategy of grouping survey items was a compromise because of the length of the survey, as people process information in chunks better than long strings of information. The 191 self-efficacy questions were divided into 16 pages of an electronic survey with each page representing a theme of professional competencies, as shown in Table 1. The grouping system had a potential impact on respondents' answering behavior. If they considered the competency items under the same group to be measuring similar concepts they might not distinguish carefully between the different statements. The data trend revealed that respondents came up with a similar level of self-efficacy for the initial items under the same category. However, the EFA results showed that the fifth factor (coordination and collaboration) had items from four different competency categories (teamwork, client serving, data recording and documentation, and coordinating and planning), indicating that the students' answers were not completely biased by the setup of the online survey.

Conducting an exploratory factor analysis with 191 items requires a large data set to catch all the granular variances. It is confounding that a larger sample size was desired due to a large number of survey items, but the length of the survey created barriers for student participation in the survey. When I performed a robustness check that used all the data collected for exploratory factor analysis (n=434), the parallel analysis suggested an initial solution of an eight-factor model. Also, during the development of SEIPEC, many competency groups were deleted in the process. This obvious discrepancy between the professional competency required by industry and that perceived by students indicated that the inventory cannot yet be treated as a comprehensive career assessment for all professional engineering competencies. The current version of SEIPEC measures the four factors well but not all professional competencies expected for engineers.

As discussed earlier in this chapter, for the observed means differences between male and female students as well as between students with various extracurricular experiences, I was not able to identify the source of the group variances. So far, this is a limitation for the research and these findings could be further explained through future work.

Also, the data collection happened at a single institution where the majority of the students surveyed are traditional-aged college students. Because professionals in the workplace recognize communication and coordination as an important competency while students in school did not, including nontraditional students (who have work experience prior to enrollment) in the sample might present different results for factors that contribute to students' self-efficacy in professional engineering competency.

Future Work

Although the development of SEIPEC followed a rigorous process for scale development, the absence of collaboration and coordination as a distinct factor in the results through EFA and CFA indicates that there is more work to do before making SEIPEC a comprehensive tool that encompasses required professional competencies for engineering students. In addition to further verifying the missing factors related to professional competencies, a complete version of this tool will also include instructions on its administration and interpretation of the results. There are a few follow-up projects to implement in order to further develop SEIPEC.

The first step in future work regards sampling strategy. I would like to continue to sample engineering students from various types of institutions. The purpose of diversifying the sample is twofold. The first goal is to create a more representative sample pool from various institutions to test whether the current findings from a single institution still hold consistent. The second goal is to test whether a group difference exists across institutions. Because various types of institutions may vary in their mission in terms of the student population served and the organizational priorities identified, these differences could exert influence on the overall learning experience and student outcomes (Van Vught, 2008).

A qualitative study should also be carried out to understand the mindset of engineering students. Extending on the findings of the SEIPEC, I would like to know how students perceive the relationship between their future work and competencies that did not come up as distinct factors, such as collaboration and communication. Also, the qualitative study could help to understand which experiences students referred to when they were asked to evaluate their self-efficacy for professional engineering competencies.

After a more robust SEIPEC has undergone validation with a more representative sample, I would like to examine the validity of SEIPEC using other self-efficacy instruments for the workplace or engineering students, such as WS-Ei (Raelin, 2010), Engineering Self-efficacy Scale (Mamaril, 2016), and LAESE (Marra & Bogue, 2006). This step would help to increase the validity of SEIPEC. A limitation of SEIPEC is the lack of certain important competencies that are deemed to be crucial for successful performance in the workplace (e.g., collaboration). In the current project, it was not feasible to include items from other relevant self-efficacy scales due to the considerable length of the 191-item online survey. However, this validation process would be feasible with a smaller set of SEIPEC items.

Another future project is to include practicing engineers in the sample and test for what type of factor structure shows up using exploratory and confirmatory analysis with the initial 191 items. As shown in a few previous studies on professional engineers' perceptions of highly valued and necessary engineering competencies (Passow, 2012; Bohlscheid & Clark, 2012), the perceptions of engineering students and engineering professionals differ. This change is also expected when a new graduate goes through the transition to their first professional job after graduation (Passow, 2012). Comparison of these two results could reveal a shift of mindset when engineering students become practicing engineers. Ideally, the data would be obtained through a longitudinal survey. However, due to the anonymous nature of the survey data collection, the best alternative would be to conduct a cross-sectional study in order to sample currently practicing professional engineers.

Finally, the implementation and intervention of self-assessments were found to be key to generating positive change in students' learning (Panadero, Jonsson, & Botella, 2017). Because this tool is designed for practice and requires clear instructions on its administration and interpretation, I will need to write user instructions for use in various settings, including self-administration by students, counseling sessions by career counselors, and others.

Implications and Suggestions

The results of this research showed that there is still a gap between students' perceptions of required competencies in professional engineering jobs and workplace expectations. As indicated by Walther et al. (2011), the formation of an engineering identity among engineering students takes place both in and outside of the classroom, and the learning process is often complex. The goal of developing SEIPEC is to provide a validated career assessment that students and educators can use to initiate a meaningful reflection on career development and career decision-making. Despite the limitations identified for the current version of SEIPEC, the future version of this career assessment holds potential as an easy-access, quick self-assessment that could be integrated into engineering education programs with other assessment tools. Although it is not a direct measure of students' actual abilities and skills, such a tool could be used in many ways by students, instructors, and program administrators to help students better prepare for the school-to-work transition by promoting more informed decisions.

Students

Students can use the results from taking the SEIPEC to generate reflections on their competency development process. For example, with a lower score in self-efficacy for F2 (use of tools and technologies), a student can reflect on previous coursework regarding how to use tools and technologies to solve engineering problems. Then they can form a plan to develop their competencies in those learned tools and technologies, or reevaluate their learning experiences and interests in performing certain tasks. This reflection could help students to become more aware of their acquired knowledge and skills. A strong understanding of one's competency lays a foundation for informed career decision making (Sampson, Reardon, Peterson, & Lenz, 2004).

Faculty and Instructors

Instructors could use this as a formative assessment tool to measure learning outcomes in specific courses and understand how various courses contribute to students' perception development regarding professional proficiencies. Program administrators may use the results from students' self-assessment to identify gaps in the curricular and program setup, thus creating more opportunities for students to develop those skills.

Career Coaches and Academic Advisors

Career coaches and academic advisors can use students' SEIPEC results to help them make career-related decisions. For example, if a student has a low level of self-efficacy regarding sustainability and societal impact, an academic advisor/career coach can start a conversation that helps the student to identify and engage courses or extracurricular projects that provide opportunities to develop such competencies. The advisor/career coach can also probe students' understanding of these competencies and help students to articulate their competencies to prepare for future interviews. If a student has low levels of self-efficacy across all factors in SEIPEC, the results should be considered a signal to start a conversation about the student's motivation and learning experiences. In this case, the student may identify reasons that lead to low confidence, thus making decisions to explore other career options beyond engineering or developing plans to increase their self-efficacy in professional engineering competencies. Evaluating the experience gained through experiential learning such as internships and co-ops is another context in which to use SEIPEC. Students can take the assessment before joining an internship program and take it again after the internship. Academic advisors/career coaches can use these pre and post results to help students reflect on their growth during the experience, and discuss the differences between academic settings and the workplace.

In summary, this research identified the latent factors that contribute to engineering students' self-efficacy for professional engineering competency. The findings from this research also indicate that using self-assessment to evaluate students' self-efficacy for professional engineering competencies has the potential to add an important reflection component to learning experiences.

CONCLUSION

In this project, I utilized the Engineering Competency Model as a framework to develop an inventory that measured students' self-efficacy in the professional engineering competencies from ECM. Using empirical data collected at a large research university, I identified four latent factors that contribute to self-efficacy in professional engineering competency for engineering students. The four factors are sustainability and societal impact (F1), use of tools and technologies (F2), health and safety (F3), and engineering economics (F4), reflecting four of the twenty competency groups specified in ECM Tier 3 and Tier 4.

Twenty questions were identified to measure the four latent constructs of engineering students' self-efficacy in professional engineering competency. The questions are prompted by the self-efficacy question, "How much confidence do you have in completing…?" and were followed by a specific professional engineering competency statement. The 20 items assess students' self-efficacy towards environmental and public interest concerns in engineering practice, operational safety in engineering practice, application of tools and technology in engineering problem solving, and analysis of the economic decisions associated with engineering practice.

Further analysis of group differences indicates that self-efficacy in professional engineering competency varies across groups. Specifically, differences were observed between male and female respondents on their self-efficacy in the competencies "use of tools and technologies to solve problems" and "engineering economics." Another group difference observed is that students with three or more extracurricular engineering project experiences reported higher self-efficacy on "use of tools and technologies to solve problems" than those no experience of this type. With the existing data, the source of the observed difference cannot be identified. The difference can either be the true difference between groups, or it could be caused by the measurement tool itself.

Unlike previous work on measuring engineering students' self-efficacy that focused on their learning experience as students, SEIPEC aims at measuring self-efficacy in professional competencies that are required for professional engineers at work. When comparing the items from SEIPEC with previous scales such as Engineering Self-efficacy Scales (Mamaril, 2014) and

LAESE (Marra & Bogue, 2006), there is no identical or similar question because SEIPEC focuses on professional workplace competencies for engineering students while the aforementioned scales focus on students' educational experience, such as learning.

As the first step towards developing a career assessment that focuses on engineering students' self-efficacy towards professional competencies, there are limitations associated with this project. The major limitation of the design is the length of the initial survey. This created challenges for both data collection and data analysis. Also, the sample was collected from a single institution with many respondents in their first-year and second-year of college having no engineering experience outside of the school setting, Students from other institutions might have different levels of exposure to professional workplaces.

Future work on this project includes seeking a better understanding of the awareness and recognition of professional engineering competency among engineering students. To increase the construct validity of SEIPEC, new rounds of data collection would be necessary. With a larger sample set, I am hoping to test whether the four-factor model is still the best model to explain the common variance. Also, triangulation with objective measurements of students' achievement as well as qualitative data will contribute to the explanation for the differences observed among groups. A goal of this series of investigations is to provide an applicable career assessment that students and educators (e.g., instructors, advisors, coaches) can use to gain strong self-knowledge and make informed educational and career decisions. So in the future development of this project, a user's manual is needed.

SEIPEC is the first project to incorporate self-efficacy measurement with professional competencies in the context of engineering work for college engineering students. The development of SEIPEC explores the students' perception of professional engineering competency and identifies four latent factors that contribute to students' self-efficacy in professional engineering competency. The findings in this project lead to a better understanding of the gap between school and workplace perceived by college engineering students and provides directions for future work to further investigate the professional competency development in post-secondary engineering education.

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APPENDIX A. CONCEPT MAP OF THE LITERATURE

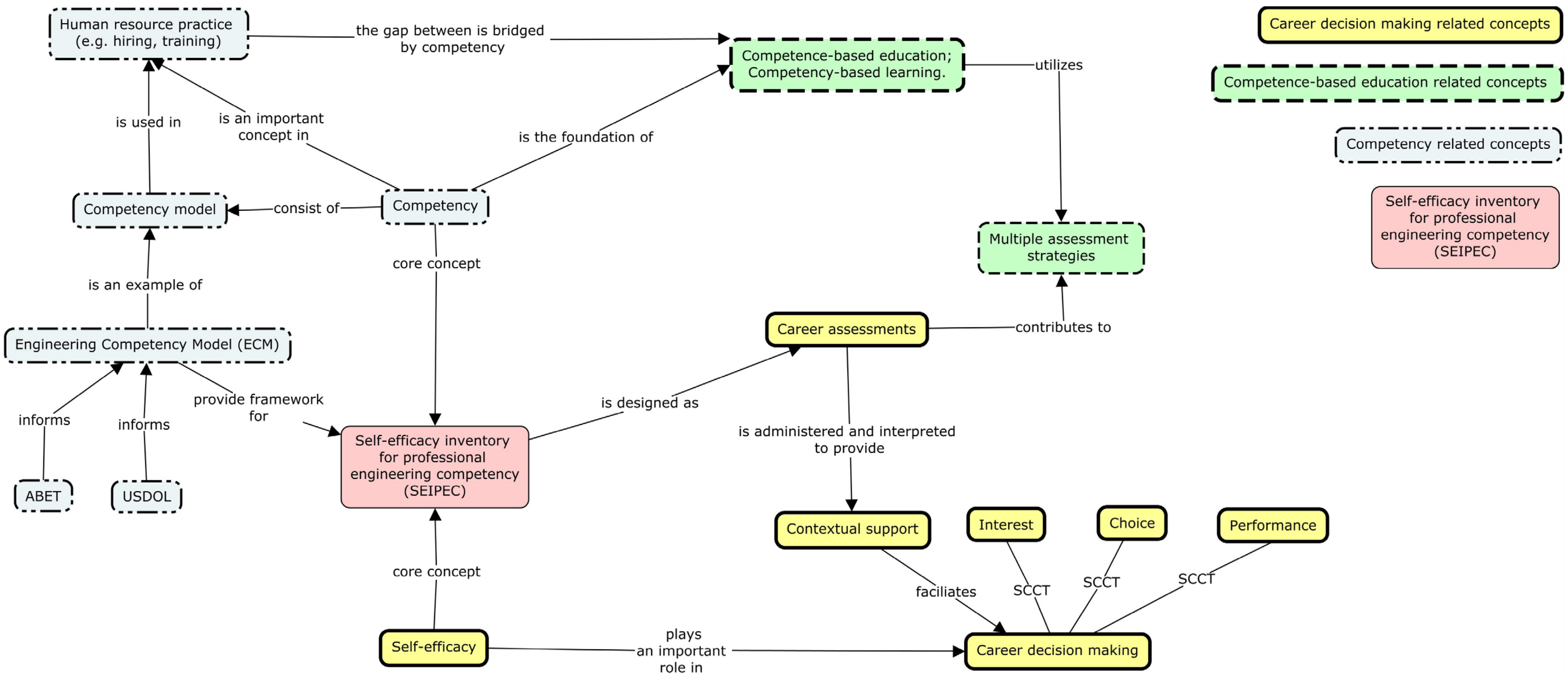

Figure 5. Concept Map of the Literature

APPENDIX B. ENGINEERING COMPETENCY MODEL VISUAL STRUCTURE BY AMERICAN ASSOCIATIONS OF ENGINEERING SOCIETIES

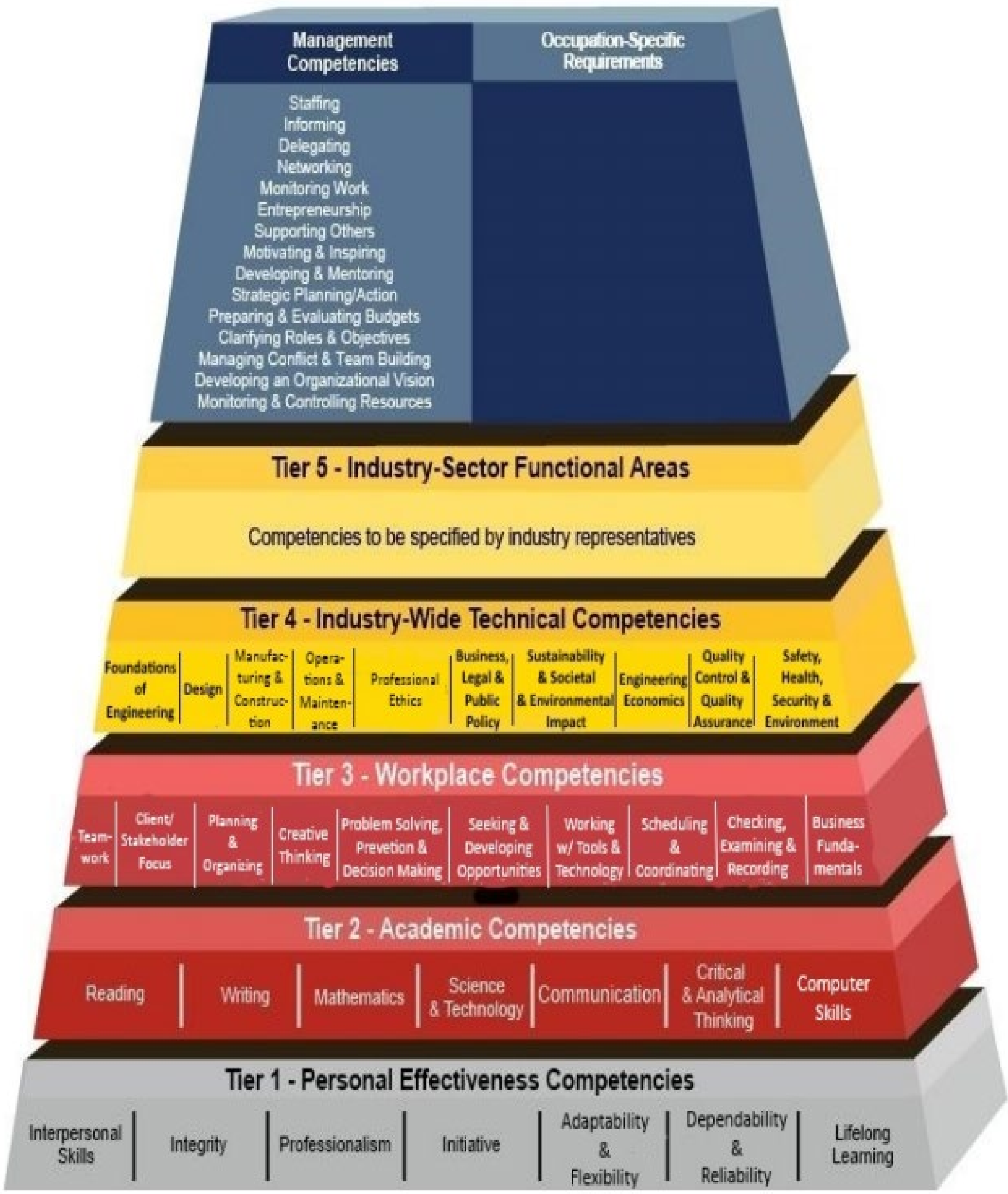

Figure 6. Engineering Competency Model Visual Representation

APPENDIX C. ONLINE SURVEY SCREENSHOT

PURDUE
UNIVERSITY®

Default Question Block

INFORMATION SHEET

Development and validation of an engineering competencies self-efficacy inventory
Prof. Joyce Main
School of Engineering Education
Purdue University

What is the purpose of this study?
This project aims at developing an inventory that helps engineering students to evaluate themselves regarding various professional competencies required for engineers. An engineering student could use the results from the inventory to identify strengths and weaknesses, as well as learn the language to describe their skills during job interviews, etc. Your participation contributes a lot to the development of this tool, which will help engineering students with making informed career decisions.

What will I do if I choose to be in this study?
You are about to complete a self-assessment of your confidence in 190 common tasks and competencies required for professional engineers. The 190 questions were developed based on the Engineering Competency Model by Employment and Training Administration from United States Department of Labor.

Will I receive payment or other incentive?
You will have a chance to win a $50 gift card. The odds of winning is approximately 1 out of every 10 people.

How long will I be in the study?
Completing the survey will take about 20-30 minutes. You can take a break and continue the survey with the same link. Please note that the survey link will expire in a week after you start it.

Will information about me and my participation be kept confidential?
In any report that we make, individual participants will not be identifiable. The data will be stored in a restricted access laboratory and/or in a password-protected secure data repository. The data will be accessible only to researchers and consultants working on relevant projects. The project's research records may be reviewed by the National Science Foundation, and by departments at Purdue University responsible for regulatory and research oversight.

What are my rights if I take part in this study?
Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Who can I contact if I have questions about the study?
If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Dr. Joyce Main (765-496-6052) or Rose Xu (xu729@purdue.edu).

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu)or write to: Human Research Protection Program - Purdue University | Ernest C. Young Hall, Room 1032 | 155 S. Grant St.,West Lafayette, IN 47907-2114

By clicking the "->" button below, you will proceed to the survey.

In the next few pages you will read statements involving tasks and competencies needed for a professional engineer or closely related position.

Take your time to read them one by one, and rate for each task how confident you are to accomplish it. Hover your mouse to the **highlighted key terms**, you can find a brief description of the competence group.

Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Note: Some tasks may not apply to your field of engineering very much. In these cases, please try to imagine doing the task and rate your confidence. At the bottom of the page, you'll have a chance to indicate whether these tasks are relevant to your field of engineering.

When you rate your confidence, try to use the full range. Below is an example of the scale of confidence you will use throughout the survey.

1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
○	○	○	○	○

(1/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **14** tasks associated with **teamwork** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Contribute to your team's effort to achieve goals.	○	○	○	○	○
2. Draw upon team members' strengths during	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
collaboration.					
3. Serve as a either leader or follower depending on the need of the team.	O	O	O	O	O
4. Learn new knowledge and skills from other team members.	O	O	O	O	O
5. Instruct others and provide mentorship.	O	O	O	O	O
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Assist others when they cannot finish their work.	O	O	O	O	O
7. Encourage others to express their ideas.	O	O	O	O	O
8. Develop a friendly working relationship with team members.	O	O	O	O	O
9. Strive to build consensus toward a shared goal during team disagreements.	O	O	O	O	O
10. Use a supportive manner when delivering criticism.	O	O	O	O	O
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
11. Respond appropriately to negative feedback.	O	O	O	O	O
12. Communicate effectively with all members of a multi-disciplinary team.	O	O	O	O	O
13. Use tools (e.g., email, online meeting) to collaborate with team members virtually.	O	O	O	O	O
14. Handle conflicts to achieve positive results for all parties.	O	O	O	O	O

How much relevance do these teamwork related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
O	O	O

(2/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **14** tasks associated with **serving clients** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Identify clients, both inside and outside of my organization.	○	○	○	○	○
2. Ask clarifying questions to understand a client's needs.	○	○	○	○	○
3. Anticipate what a client may need in the future.	○	○	○	○	○
4. Provide quick assistance to address a client's concerns.	○	○	○	○	○
5. Be transparent with a client about the timeline and quality standards of a project.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Identify and propose appropriate solutions for a client.	○	○	○	○	○
7. Actively seek feedback from a client.	○	○	○	○	○
8. Adjust proposed solutions based on a client's feedback.	○	○	○	○	○
9. Communicate boundaries when a client's needs are unreasonable.	○	○	○	○	○
10. Be professional when working with a client.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
11. Develop a cooperative working relationship with a client.	○	○	○	○	○
12. Remain calm when interacting with hostile clients.	○	○	○	○	○
13. Maintain communication with clients during and after a project.	○	○	○	○	○
14. Communicate promptly with clients about the decisions that affect them.	○	○	○	○	○

How much relevance do these client-focus related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant

(3/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **9** tasks associated with **creative thinking** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Learn methods that facilitate creative thinking.	○	○	○	○	○
2. Consider past successful approaches while being open to new ones.	○	○	○	○	○
3. Integrate seemingly unrelated information to develop creative solutions.	○	○	○	○	○
4. Reframe problems to find fresh approaches.	○	○	○	○	○
5. Develop innovative methods of using resources when resources are limited.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Find new ways to add value to a team.	○	○	○	○	○
7. Understand how parts of a system are inter-related.	○	○	○	○	○
8. Monitor patterns and trends to see a bigger picture.	○	○	○	○	○
9. Identify potential changes for a system to improve performance.	○	○	○	○	○

How much relevance do these creative thinking related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(4/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **17** tasks associated with **problem-solving** on this page. How much confidence do you have in completing the following tasks?

1-No	2-Very little	3-Moderate	4-Much	5-Complete

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Anticipate or recognize a problem's existence.	○	○	○	○	○
2. Research the history of an existing problem.	○	○	○	○	○
3. Analyze existing conditions to define the critical issues of a problem.	○	○	○	○	○
4. Evaluate the importance of a problem.	○	○	○	○	○
5. Recall previously learned knowledge relevant to a problem.	○	○	○	○	○
6. Formulate plans for preventing the same problem from reoccurring after solving a problem.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
7. Consider the cause and effects of a problem.	○	○	○	○	○
8. Generate multiple solutions for a problem.	○	○	○	○	○
9. Evaluate the alternative solutions (e.g. strengths and weaknesses, costs and benefits, short-term and long-term consequences).	○	○	○	○	○
10. Monitor patterns and trends to see a bigger picture.	○	○	○	○	○
11. Decisively choose a solution after evaluating options.	○	○	○	○	○
12. Make decisions even in highly ambiguous situations.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
13. Develop a realistic approach to implementing a chosen solution.	○	○	○	○	○
14. Document the process of problem-solving, such as the nature of the problem, actions taken, and outcome.	○	○	○	○	○
15. After solving a problem, evaluate the outcomes of the solution.	○	○	○	○	○
16. Assess the needs for alternative approaches after	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
executing a solution.					
17. Expedite projects by working on tasks that can be done simultaneously.	○	○	○	○	○

How much relevance do these problem-solving related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(5/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **11** tasks associated with **working with tools and technologies** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Identify potential tools (e.g., hardware and software) appropriate to the task at hand.	○	○	○	○	○
2. Select proper tools for a project.	○	○	○	○	○
3. Apply selected tools (or technological solutions) to the tasks at hand.	○	○	○	○	○
4. Operate tools in accordance with operating procedures and safety standards.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Identify potential risks related to the use of tools and equipment.	○	○	○	○	○
6. Interpret the results obtained from an engineering tool.	○	○	○	○	○
7. Learn to apply a new or updated tool to solve an engineering problem.	○	○	○	○	○
8. Learn to maintain and troubleshoot tools and technologies.	○	○	○	○	○

1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
9. Maintain engineering tools and equipment.	○	○	○	○	○
10. Take the appropriate corrective action when identifying causes of error for a tool.	○	○	○	○	○
11. Develop alternatives to complete a task if a desired tool is not available.	○	○	○	○	○

How much relevance do these working with tools related tasks have with your intended career/job?

Highly relevant	Moderate relevant	Not relevant
○	○	○

(6/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **12** tasks associated with **recording and documentation** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Use systematic approaches to gather data.	○	○	○	○	○
2. Record data in documentation.	○	○	○	○	○
3. Detect and correct errors in data.	○	○	○	○	○
4. Route errors to the appropriate person to correct documentation.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Select appropriate forms for documentation.	○	○	○	○	○
6. Complete appropriate forms quickly and completely.	○	○	○	○	○
7. Forward forms to the appropriate personnel in a timely manner.	○	○	○	○	○
8. Prioritize tasks that require immediate attention.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
9. Verify that all information is up-to-date and accurate.	O	O	O	O	O
10. Keep documents up-to-date and readily accessible (e.g., driver logs, flight records, repair records).	O	O	O	O	O
11. Make notes on important changes when updating documents.	O	O	O	O	O
12. File data and documentation in accordance with requirements.	O	O	O	O	O

How much relevance do these recording and documentation related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
O	O	O

(7/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **16** tasks associated with **planning and coordinating** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Formulate effective strategies to complete a project.	O	O	O	O	O
2. Break down the project into specific tasks.	O	O	O	O	O
3. Estimate personnel, costs, and other resources needed.	O	O	O	O	O
4. Allocate time, resource, and personnel effectively.	O	O	O	O	O
5. Delegate the tasks to team members.	O	O	O	O	O
6. Use tools to assist with planning (e.g., Gantt charts, precedence diagrams, critical path methods).	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
7. Create schedule so the work is completed on time.	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
8. Keep track of details to ensure work is performed accurately and completely.	○	○	○	○	○
9. Develop plans to address anticipated obstacles to project completion.	○	○	○	○	○
10. Organize work area to accomplish work more efficiently.	○	○	○	○	○
11. Prioritize multiple competing tasks.	○	○	○	○	○
12. Effectively execute the tasks according to their urgency and importance.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
13. Plan for the dependencies of one task on another.	○	○	○	○	○
14. Take corrective actions if the project goes off track.	○	○	○	○	○
15. Coordinate meetings for all involved parties.	○	○	○	○	○
16. Use technology to facilitate information sharing.	○	○	○	○	○

How much relevance do these planning and coordinating related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(8/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **10** tasks associated with **foundations of engineering** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Understand the basic science and technology principles related to your field of engineering practice.	○	○	○	○	○

2. Analyze a project or product to

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
identify the engineering/science principles used.	○	○	○	○	○
3. Use knowledge and principles from natural science (e.g., physics/chemistry/biology) to help solve engineering problems.	○	○	○	○	○
4. Apply scientific inquiry methods in natural science to engineering projects.	○	○	○	○	○
5. Integrate engineering knowledge, principles, and concepts to solve engineering problems.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Consider public input when exploring technical possibilities.	○	○	○	○	○
7. Evaluate societal/cultural perspectives in the development of a current project. (e.g., local, state, or national culture or history and related societal trends)	○	○	○	○	○
8. Identify the potential contribution of emerging technology to the public good.	○	○	○	○	○
9. Compare the technical and nontechnical features of alternative courses of action.	○	○	○	○	○
10. Discuss and evaluate alternative solutions with decision-makers and stakeholders.	○	○	○	○	○

How much relevance do these foundations of engineering related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(9/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **23** tasks associated with **engineering design** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Meet well-defined design requirements.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
2. Identify project requirements and constraints on various aspects (e.g., technical, environmental, economic, regulatory, cultural and others).	O	O	O	O	O
3. Gather information to fully understand the design problem.	O	O	O	O	O
4. Collect data to help with defining a design problem.	O	O	O	O	O
5. Analyze the advantages and drawbacks of various design options.	O	O	O	O	O
6. Analyze a project's constructability or manufacturing feasibility.	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
7. Apply lessons learned from other design projects.	O	O	O	O	O
8. Maintain up to date knowledge to accomplish specific design objectives (e.g., knowledge of current types of systems, equipment, information technology, and specifications).	O	O	O	O	O
9. Consider ergonomics when creating products for users.	O	O	O	O	O
10. Choose the appropriate strategies to test a design (e.g., rapid prototyping).	O	O	O	O	O
11. Use software related to your engineering discipline.	O	O	O	O	O
12. Apply concepts of security (e.g. physical or cyber) to ensure secure operations.	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
13. Review research articles to assist the design process.	O	O	O	O	O
14. Pursue continuing education to increase the depth of technical knowledge.	O	O	O	O	O
15. Identify the impact of an engineering design to the public health, safety, and welfare.	O	O	O	O	O
16. Assess environmental impact when designing.	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
17. Apply concepts of risk, reliability, and/or uncertainty in engineering design decision making.	O	O	O	O	O
18. Consider both current and future conditions when defining a design problem.	O	O	O	O	O
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
19. Calculate the probability and frequency of the occurrence of risks in design.	O	O	O	O	O
20. Compare alternative design options based on risk analysis.	O	O	O	O	O
21. Apply prototyping methods to the design process.	O	O	O	O	O
22. Design experiments to test the potential effectiveness of a proposed solution.	O	O	O	O	O
23. Understand and apply the difference between accuracy and precision.	O	O	O	O	O

How much relevance do these engineering design related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
O	O	O

You just got through two thirds of the 190 questions! Feel free to take a break before you continue.

The next few competency groups are related to the industrial aspects of engineering works.

(10/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **7** tasks associated with **manufacturing, construction, and operation** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Identify and prioritize the various requirements (e.g., the technical, environmental, economic, regulatory, and other requirements).	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
2. Gather and analyze information to make plans.	○	○	○	○	○
3. Compare some alternatives to select the optimum approach.	○	○	○	○	○
4. Develop standard operating procedures to make the operation of engineered systems safe and reliable.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Allocate resources to ensure safety and reliability of engineered systems.	○	○	○	○	○
6. Coordinate trainings for personnel (e.g., technicians, supervisors, and workers) to operate and maintain engineered systems.	○	○	○	○	○
7. Choose among alternative operation and maintenance methods.	○	○	○	○	○

How much relevance do these manufacturing, construction, and operation related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(11/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **11** tasks associated with **professional ethics** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Practice engineering according to Code of Ethics for Engineers.	○	○	○	○	○
2. Encourage others to behave ethically.	○	○	○	○	○
3. Use company time and property responsibly.	○	○	○	○	○
4. Perform work-related duties according to laws, regulations, contract provisions, and company	○	○	○	○	○

policies.	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Respect the need for confidentiality, when appropriate.	○	○	○	○	○
6. Analyze a situation involving multiple conflicting professional and ethical interests.	○	○	○	○	○
7. Distinguish between a legal matter and an ethical matter.	○	○	○	○	○
8. Identify ethical dilemmas.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
9. Bring together appropriate resources to resolve an ethical dilemma.	○	○	○	○	○
10. Work with supervisors to formulate solutions to an ethical dilemma.	○	○	○	○	○
11. Report to high-level management or public authorities when there are serious concerns regarding the public health, safety, and welfare.	○	○	○	○	○

How much relevance do these professional ethics related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(12/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **7** tasks associated with **quality control and assurance** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Understand basic concepts associated with quality.	○	○	○	○	○
2. Use quality management to ensure quality levels are maintained.	○	○	○	○	○
3. Seek new approaches and techniques to improve quality.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
4. Employ inspections to maintain the quality.					
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Prepare quality assurance specifications for a project.					
6. Review quality control procedures on a project.					
7. Analyze the impact of quality control on project performance.					

How much relevance do these quality control and assurance related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant

(13/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **7** tasks associated with **sustainability and societal impact** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Strive to minimize waste and reduce resource use.					
2. Understand the environmental effects of a product at every stage of its existence (from the extraction of materials through production to disposal and beyond).					
3 Safeguard the public interest.					
4. Ensure equipment and systems are designed to minimize environmental impact.					
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
5. Upgrade levels of efficiency in resource consumption.					
6. Analyze the impacts of a project on diverse stakeholders.					

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
7. Deliver presentations to the public regarding the social and environmental impacts of a project.	○	○	○	○	○

How much relevance do these sustainability and societal impact related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

(14/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **15** tasks associated with **health, safety, and security in engineering practice** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Take precautions to prevent work-related injuries and illness.	○	○	○	○	○
2. Comply with federal, state, local, and environmental regulations, as well as company health and safety policies.	○	○	○	○	○
3. Implement continuous improvement in health, safety, and/or environmental practices.	○	○	○	○	○
4. Take appropriate steps to address the risks of hazards and unsafe conditions.	○	○	○	○	○
5. Follow organizational protocols for workplace emergencies (e.g., safe evacuation and emergency response).	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Maintain a sanitary and clutter-free work environment.	○	○	○	○	○
7. Properly handle and dispose of hazardous materials.	○	○	○	○	○
8. Engage in safety training.	○	○	○	○	○
9. Use equipment and tools safely.	○	○	○	○	○

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
10. Use appropriate personal protective equipment.	O	O	O	O	O
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
11. Understand the legal rights of workers regarding workplace safety and protection from hazards.	O	O	O	O	O
12. Report injuries, incidents, and workplace hazards to a supervisor.	O	O	O	O	O
13. Contribute to the discussion of safety concerns in the workplace (e.g., making suggestions as appropriate).	O	O	O	O	O
14. Evaluate the safety aspects of design alternatives for a process, project component, or product.	O	O	O	O	O
15. Identify and apply the most current safety-related regulatory requirements (e.g., to a process, project, product or specific area of engineering practice).	O	O	O	O	O

How much relevance do these health, safety, and security in engineering related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
O	O	O

(15/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **5** tasks associated with **engineering economics** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Estimate the cost of a project, product, or process (e.g., maintenance and repair, and replacement costs for equipment, materials, assembly, inspection, modification, quality assurance)	O	O	O	O	O

modification, quality assurance).

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
2. Calculate the financial indicators of a project (e.g., return on investment, present worth, or annual cost and benefit).	O	O	O	O	O
3. Recognize the potential economic risks associated with a project or product (e.g., warranty costs).	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
4. Conduct comparative cost analysis on various designs of a project or product.	O	O	O	O	O
5. Communicate with relevant personnel about project economics, costs, and financial analysis.	O	O	O	O	O

How much relevance do these engineering economics related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
O	O	O

(16/16) Choose a setting that allows you to envision accomplishing these tasks, such as a class project, student organization activities, internship/co-op, and a potential full-time job.

Read each statement and rate your level of confidence. There are **13** tasks associated with **business, legal, and policy** on this page. How much confidence do you have in completing the following tasks?

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
1. Understand the mission and functions of an organization.	O	O	O	O	O
2. Understand the potential impact of your performance on the success of an organization.	O	O	O	O	O
3. Grasp the potential impact of the organization's well-being on employees.	O	O	O	O	O
4. Understand market trends in the industry.	O	O	O	O	O
5. Stay current on organizational strategies to maintain competitiveness.	O	O	O	O	O

	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
6. Recognize major challenges faced by an organization and industry.	○	○	○	○	○
7. Stay informed on the key strategies to address the challenges faced by an organization.	○	○	○	○	○
8. Distinguish among the various kinds of engineering practices, including corporate, academic, government, consulting, and self-employment.	○	○	○	○	○
9. Describe and interpret applicable codes (i.e., rules and specifications) in design and manufacturing/construction.	○	○	○	○	○
10. Identify applicable standards in preparing specifications for manufacturing/construction.	○	○	○	○	○
	1-No confidence	2-Very little confidence	3-Moderate confidence	4-Much confidence	5-Complete confidence
11. Prepare and interpret contract documents (e.g., coordinating plans, specifications, and construction contract provisions).	○	○	○	○	○
12. Engage with the various types of policy-making bodies (e.g., administrative, legislative, private, and quasi-public) pertinent to a specific area of practice.	○	○	○	○	○
13. Describe how public policy affects engineering practice in your engineering discipline.	○	○	○	○	○

How much relevance do these business, legal, and policy related tasks have with your intended career/job?

Highly relevant	Somewhat relevant	Not relevant
○	○	○

Thank you very much for make it this far!

We want to know a little more about your engineering related experiences, such as your engineering degree and number of internship experiences. This part will take 2-3 minutes.

What degree level are you pursuing?

- Bachelor's
- Master's

What year level are you in?

- First year
- Sophomore
- Junior
- Senior
- 5th year and after

What year level are you in?

- First year
- Second year
- 3rd year and after

What's your current major?

What's your bachelor's degree major? (if not listed, please choose the closest major) If not listed, please indicate in the box below.

▼

Other majors (if NA is chosen):

How many experiences do you have within the below categories?

	0	1	2	3 and more
Engineering internship	○	○	○	○
Engineering co-op sessions	○	○	○	○
Engineering work experience (full-time)	○	○	○	○
Engineering projects (academic)	○	○	○	○
Engineering projects (extracurricular)	○	○	○	○
Non-Engineering job (part time/full time)	○	○	○	○

Do you have any family members or close connections who are (or used to be) an engineer?

- Yes
- No

Did you get a chance to know their work experiences as an engineer?

- Yes, extensively.
- Yes, but limited.
- No.

Do you enjoy engineering in general?

- Yes
- No

- Not sure

Are you going to pursue a job in engineering?

- Yes, I plan to.
- I'm not sure.
- No, probably not.
- I'm going to pursue further education, then a job in engineering.
- I'm going to pursue further education in a field outside of engineering.

This is the last page of this survey!

Are you a first generation college student? (i.e. whose parent(s)/legal guardian(s) have not completed a bachelor's degree)

- Yes
- No
- Prefer not to answer

Do you identify as an international student?

- Yes
- No
- Prefer not to answer

What gender do you identify with?

- Male
- Female
- Non-binary
- Gender non-conforming
- Not listed here (other)
- Prefer not to answer

Do you identify yourself as a veteran?

- Yes
- No
- Prefer not to answer

Do you identify yourself as disabled?

- Yes
- No
- Prefer not to answer

Please leave your email address if you'd like to enter the drawing of the gift cards.

Can we follow up with you in the future regarding this study?

- Yes
- No

You can save and come back to finish the survey with the same link. Please finish this survey within a week, or the link will expire. If you have any questions about the survey, please contact Rose Xu at xuxinrui@purdue.edu.

APPENDIX D. 191 COMPETENCY STATEMENTS LEFT AFTER THE PILOT STUDY

"How much confidence do you have in accomplishing…"

T3 -Teamwork

1. Contribute to your team's effort to achieve goals.
2. Draw upon team members' strengths and weaknesses during collaboration.
3. Serve as a either leader or follower depending on the need of the team.
4. Learn new knowledge and skills from other team members.
5. Instruct others and provide mentorship.
6. Assist others when they cannot finish their work.
7. Encourage others to express their ideas.
8. Develop a friendly working relationship with team members.
9. Strive to build consensus toward a shared goal during team disagreements.
10. Use a supportive manner when delivering criticism.
11. Respond appropriately to positive and negative feedback.
12. Communicate effectively with all members of a multi-disciplinary team.
13. Use tools (e.g., email, online meeting) to collaborate with team members virtually.
14. Handle conflicts to achieve positive results for all parties.

T3- Client/stakeholder focus

15. Identify clients, both inside and outside of my organization.
16. Ask clarifying questions to understand a client's need.
17. Identify the services needed by a client.
18. Anticipate what a client may need in the future.
19. Provide quick assistance to address a client's concerns.
20. Be transparent with a client about the timeline and quality standards of a project.
21. Identify and propose appropriate solutions for a client.
22. Actively seek feedback from a client.
23. Adjust proposed solutions based on a client's feedback.
24. Communicate boundaries when a client's needs are unreasonable.
25. Be professional when working with a client.
26. Develop a cooperative working relationship with a client.
27. Remain calm when interacting with hostile clients.
28. Maintain communication with clients during and after a project.
29. Communicate promptly with clients about the decisions that affect them.

T3- Creative and systems thinking

30. Learn methods that facilitate creative thinking.
31. Consider past successful approaches while being open to new ones.
32. Integrate seemingly unrelated information to develop creative solutions.
33. Reframe problems to find fresh approaches.

34. Develop innovative methods of using resources when resources are limited.
35. Find new ways to add value to a team.
36. Understand how parts of a system are inter-related.
37. Monitor patterns and trends to see a bigger picture.
38. Identify potential changes for a system to improve performance.

T3- Problem-solving and decision making

39. Anticipate or recognize a problem's existence.
40. Research the history of an existing problem.
41. Analyze existing conditions to define the critical issues of a problem.
42. Evaluate the importance of a problem.
43. Recall previously learned knowledge relevant to a problem.
44. Formulate plans for preventing the same problem from reoccurring after solving a problem.
45. Consider the cause and effects of a problem.
46. Generate multiple solutions for a problem.
47. Evaluate the alternative solutions (e.g. strengths and weaknesses, costs and benefits, short-term and long-term consequences).
48. Decisively choose a solution after evaluating options.
49. Make decisions even in highly ambiguous situations.
50. Develop a realistic approach to implementing a chosen solution.
51. Document the process of problem-solving, such as the nature of the problem, actions taken, and outcome.
52. After solving a problem, evaluate the outcomes of the solution.
53. Assess the needs for alternative approaches after executing a solution.
54. Expedite projects by working on tasks that can be done simultaneously.

T3- Working with tools and technologies

55. Identify potential tools (e.g., hardware and software) appropriate to the task at hand.
56. Select proper tools for a project.
57. Apply selected tools (or technological solutions) to the tasks at hand.
58. Operate tools in accordance with operating procedures and safety standards.
59. Identify potential risks related to the use of tools and equipment.
60. Interpret the results obtained from an engineering tool.
61. Learn to apply a new or updated tool to solve an engineering problem.
62. Learn to maintain and troubleshoot tools and technologies.
63. Apply maintenance for tool.
64. Take the appropriate corrective action when identifying causes of error for a tool.
65. Develop alternatives to complete a task if a desired tool is not available.

T3- Checking, examining and recording

66. Use systematic approaches to gather data.
67. Record data in a clear and concise way.

68. Detect and correct errors in data.
69. Route errors to the appropriate person to correct documentation.
70. Select appropriate forms for documentation.
71. Complete appropriate forms quickly and completely.
72. Forward forms to the appropriate personnel in a timely manner.
73. Prioritize tasks that require immediate attention.
74. Verify that all information is up-to-date and accurate.
75. Keep documents up-to-date and readily accessible (e.g., driver logs, flight records, repair records).
76. Make notes on important changes when updating documents.
77. File data and documentation in accordance with requirements.

T3 – Planning, organizing, scheduling and coordinating

78. Formulate effective strategies to complete a project.
79. Break down the project into specific tasks.
80. Estimate personnel, costs, and other resources needed.
81. Allocate time, resource, and personnel effectively.
82. Delegate the tasks to team members.
83. Use tools to assist with planning (e.g., Gantt charts, precedence diagrams, critical path methods).
84. Create schedule so the work is completed on time.
85. Keep track of details to ensure work is performed accurately and completely.
86. Develop plans to address anticipated obstacles to project completion.
87. Organize work area to accomplish work more efficiently.
88. Prioritize multiple competing tasks.
89. Effectively execute the tasks according to their urgency and importance.
90. Plan for the dependencies of one task on another.
91. Take corrective actions if the project goes off track.
92. Coordinate meetings for all involved parties.
93. Use technology to facilitate information sharing.

T4- Foundations of Engineering

94. Understand the basic science and technology principles related to your field of engineering practice.
95. Analyze a project or product to identify the engineering/science principles used.
96. Use knowledge and principles from natural science (e.g., physics/chemistry/biology) to help solve engineering problems.
97. Apply scientific inquiry methods in natural science to engineering projects.
98. Integrate engineering knowledge, principles, and concepts to solve engineering problems.
99. Consider public input when exploring technical possibilities.
100. Evaluate societal/cultural perspectives in the development of a current project. (e.g., local, state, or national culture or history and related societal trends)
101. Identify the potential contribution of emerging technology to the public good.

102. Compare the technical and nontechnical features of alternative courses of action.
103. Discuss and evaluate alternative solutions with decision-makers and stakeholders.

T4- Design

104. Meet well-defined requirements.
105. Identify project requirements and constraints on various aspects (e.g., technical, environmental, economic, regulatory, cultural and others).
106. Gather information to fully understand the design problem.
107. Collect data to help with defining a design problem.
108. Analyze the advantages and drawbacks of various design options.
109. Analyze a project's constructability or manufacturing feasibility.
110. Apply lessons learned from other design projects.
111. Maintain up to date knowledge to accomplish specific design objectives (e.g., knowledge of current types of systems, equipment, information technology, and specifications).
112. Consider ergonomics when creating products for users.
113. Choose the appropriate strategies to test a design (e.g., rapid prototyping).
114. Use software related to your engineering discipline.
115. Apply concepts of security (e.g. physical or cyber) to ensure secure operations.
116. Review research articles to assist the design process.
117. Pursue continuing education to increase the depth of technical knowledge.
118. Identify the impact of an engineering design to the public health, safety, and welfare.
119. Assess environmental impact when designing.
120. Apply concepts of risk, reliability, and/or uncertainty in engineering design decision making.
121. Consider both current and future conditions when defining a design problem.
122. Calculate the probability and frequency of the occurrence of risks in design.
123. Compare alternative design options based on risk analysis.
124. Apply prototyping methods to the design process.
125. Design experiments to test the potential effectiveness of a proposed solution.
126. Understand and apply the difference between accuracy and precision.

T4- Manufacturing & construction & operation and maintenance

127. Identify and prioritize the various requirements (e.g., the technical, environmental, economic, regulatory, and other requirements).
128. Gather and analyze information to make plans.
129. Compare some alternatives to select the optimum approach.
130. Develop standard operating procedures to make the operation of engineered systems safe and reliable.
131. Allocate resources to ensure safety and reliability of engineered systems.
132. Coordinate trainings for personnel (e.g., technicians, supervisors, and workers) to operate and maintain engineered systems.

133. Choose among alternative operation and maintenance methods.

T4- Professional ethics

134. Practice engineering according to Code of Ethics for Engineers.
135. Encourage others to behave ethically.
136. Use company time and property responsibly.
137. Perform work-related duties according to laws, regulations, contract provisions, and company policies.
138. Respect the need for confidentiality, when appropriate.
139. Analyze a situation involving multiple conflicting professional and ethical interests.
140. Distinguish between a legal matter and an ethical matter.
141. Identify ethical dilemmas.
142. Bring together appropriate resources to resolve an ethical dilemma.
143. Work with supervisors to formulate solutions to an ethical dilemma.
144. Report to high-level management or public authorities when there are serious concerns regarding the public health, safety, and welfare.

T4- Quality control and quality assurance

145. Understand basic concepts associated with quality.
146. Use quality management to ensure quality levels are maintained.
147. Seek new approaches and techniques to improve quality.
148. Employ inspections to maintain the quality.
149. Prepare quality assurance specifications for a project.
150. Review quality control procedures on a project.
151. Analyze the impact of quality control on project performance.

T4- Sustainability, societal and environmental impact

152. Strive to minimize waste and reduce resource use.
153. Understand the environmental effects of a product at every stage of its existence (from the extraction of materials through production to disposal and beyond).
154. Safeguard the public interest.
155. Ensure equipment and systems are designed to minimize environmental impact.
156. Upgrade levels of efficiency in resource consumption.
157. Analyze the impacts of a project on diverse stakeholders.
158. Deliver presentations to the public regarding the social and environmental impacts of a project.

T4- Safety, health, security, and environment

159. Take precautions to prevent work-related injuries and illness.
160. Comply with federal, state, local, and environmental regulations, as well as company health and safety policies.

161. Implement continuous improvement in health, safety, and/or environmental practices.
162. Take appropriate steps to address the risks of hazards and unsafe conditions.
163. Follow organizational protocols for workplace emergencies (e.g., safe evacuation and emergency response).
164. Maintain a sanitary and clutter-free work environment.
165. Properly handle and dispose of hazardous materials.
166. Engage in safety training.
167. Use equipment and tools safely.
168. Use appropriate personal protective equipment.
169. Understand the legal rights of workers regarding workplace safety and protection from hazards.
170. Report injuries, incidents, and workplace hazards to a supervisor.
171. Contribute to the discussion of safety concerns in the workplace (e.g., making suggestions as appropriate).
172. Evaluate the safety aspects of design alternatives for a process, project component, or product.
173. Identify and apply the most current safety-related regulatory requirements (e.g., to a process, project, product or specific area of engineering practice).

T4- Engineering economics

174. Estimate the cost of a project, product, or process (e.g., maintenance and repair, and replacement costs for equipment, materials, assembly, inspection, modification, quality assurance).
175. Calculate the financial indicators of a project (e.g., return on investment, present worth, or annual cost and benefit).
176. Recognize the potential economic risks associated with a project or product (e.g., warranty costs).
177. Conduct comparative cost analysis on various designs of a project or product.
178. Communicate with relevant personnel about project economics, costs, and financial analysis.

T3/T4- Business, legal and public policy

179. Understand the mission and functions of an organization.
180. Understand the potential impact of your performance on the success of an organization.
181. Grasp the potential impact of the organization’s well-being on employees.
182. Understand market trends in the industry.
183. Stay current on organizational strategies to maintain competitiveness.
184. Recognize major challenges faced by an organization and industry.
185. Stay informed on the key strategies to address the challenges faced by an organization.

186. Distinguish among the various kinds of engineering practices, including corporate, academic, government, consulting, and self-employment.
187. Describe and interpret applicable codes (i.e., rules and specifications) in design and manufacturing/construction.
188. Identify applicable standards in preparing specifications for manufacturing/construction.
189. Prepare and interpret contract documents (e.g., coordinating plans, specifications, and construction contract provisions).
190. Engage with the various types of policy-making bodies (e.g., administrative, legislative, private, and quasi-public) pertinent to a specific area of practice.
191. Describe how public policy affects engineering practice in your engineering discipline.

APPENDIX E. DESCRIPTIVE STATISTICS AND NORMALITY INDICATORS

Table 15. Descriptive Statistics for Sample 1

	N	*Mean*	*SD*	Skewness	Kurtosis
Q1_1	217	4.18	0.71	-0.59	0.17
Q1_2	217	3.90	0.74	-0.30	-0.13
Q1_3	217	4.15	0.83	-0.61	-0.46
Q1_4	217	4.06	0.82	-0.41	-0.67
Q1_5	217	3.81	0.87	-0.29	-0.62
Q1_6	217	3.88	0.76	-0.16	-0.51
Q1_7	217	3.91	0.84	-0.42	-0.40
Q1_8	217	4.17	0.80	-0.74	0.05
Q1_9	217	3.97	0.79	-0.33	-0.50
Q1_10	217	3.81	0.82	-0.48	0.10
Q1_11	217	3.66	0.77	-0.01	-0.43
Q1_12	217	3.87	0.80	-0.24	-0.51
Q1_13	217	4.21	0.82	-0.80	0.26
Q1_14	217	3.81	0.79	-0.04	-0.68
Q2_1	217	3.24	0.92	-0.12	-0.27
Q2_2	217	3.72	0.86	-0.21	-0.39
Q2_3	217	3.35	0.97	-0.10	-0.50
Q2_4	217	3.64	0.82	-0.13	-0.26
Q2_5	217	3.81	0.87	-0.46	-0.16
Q2_6	217	3.88	0.79	-0.23	-0.47
Q2_7	217	3.78	0.90	-0.56	0.00
Q2_8	217	4.03	0.82	-0.50	-0.32
Q2_9	217	3.46	0.94	-0.25	-0.07
Q2_10	217	4.38	0.80	-1.06	0.21
Q2_11	217	4.15	0.77	-0.38	-0.87
Q2_12	217	3.55	0.96	-0.15	-0.53
Q2_13	217	3.71	0.86	-0.18	-0.20
Q2_14	217	3.94	0.80	-0.48	0.10
Q3_1	217	3.82	0.81	-0.15	-0.61
Q3_2	217	4.20	0.77	-0.54	-0.56
Q3_3	217	3.71	0.92	-0.31	-0.55
Q3_4	217	3.67	0.87	-0.31	-0.32
Q3_5	217	3.82	0.86	-0.39	-0.22
Q3_6	217	3.73	0.90	-0.47	0.03
Q3_7	217	3.98	0.83	-0.48	-0.12
Q3_8	217	3.95	0.88	-0.63	0.17
Q3_9	217	3.99	0.83	-0.55	-0.22

Q4_1	217	3.97	0.76	-0.58	0.68

Table 15. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q4_2	217	*3.92*	*0.92*	-0.48	-0.45
Q4_3	217	3.94	0.81	-0.40	-0.11
Q4_4	217	4.02	0.81	-0.66	0.43
Q4_5	217	3.94	0.89	-0.46	-0.36
Q4_6	217	3.87	0.89	-0.43	-0.17
Q4_7	217	4.00	0.77	-0.36	-0.40
Q4_8	217	3.86	0.85	-0.25	-0.67
Q4_9	217	4.00	0.82	-0.55	0.08
Q4_10	217	3.88	0.82	-0.40	-0.06
Q4_11	217	3.98	0.87	-0.62	0.19
Q4_12	217	3.48	0.98	-0.22	-0.28
Q4_13	217	3.94	0.69	-0.18	-0.22
Q4_14	217	3.84	1.04	-0.42	-0.93
Q4_15	217	3.96	0.81	-0.44	-0.04
Q4_16	217	3.74	0.85	-0.49	0.13
Q4_17	217	3.91	0.92	-0.56	-0.15
Q5_1	217	3.77	0.92	-0.23	-0.51
Q5_2	217	3.76	0.85	-0.17	-0.42
Q5_3	217	3.88	0.91	-0.61	0.19
Q5_4	217	3.95	0.90	-0.57	-0.26
Q5_5	217	3.83	0.92	-0.51	-0.17
Q5_6	217	3.90	0.84	-0.53	0.25
Q5_7	217	3.91	0.91	-0.54	-0.16
Q5_8	217	3.81	0.99	-0.54	-0.25
Q5_9	217	3.70	1.00	-0.39	-0.43
Q5_10	217	3.63	0.93	-0.13	-0.68
Q5_11	217	3.70	0.93	-0.41	-0.22
Q6_1	217	3.90	0.86	-0.49	-0.34
Q6_2	217	4.11	0.88	-0.57	-0.66
Q6_3	217	3.77	0.94	-0.45	-0.48
Q6_4	217	3.82	0.95	-0.62	0.07
Q6_5	217	3.76	0.96	-0.31	-0.71
Q6_6	217	3.82	0.93	-0.41	-0.53
Q6_7	217	4.03	0.94	-0.73	-0.07
Q6_8	217	4.22	0.83	-0.95	0.64
Q6_9	217	3.90	0.90	-0.43	-0.45
Q6_10	217	3.87	0.96	-0.58	-0.13
Q6_11	217	4.00	0.84	-0.51	-0.15

Q6_12	217	4.02	0.88	-0.48	-0.45
Q7_1	217	3.98	0.74	-0.37	-0.09

Table 15. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q7_2	217	4.20	0.76	-0.55	-0.47
Q7_3	217	3.41	0.96	-0.06	-0.49
Q7_4	217	3.62	0.91	-0.20	-0.42
Q7_5	217	3.93	0.88	-0.41	-0.63
Q7_6	217	3.62	0.99	-0.28	-0.61
Q7_7	217	3.88	0.87	-0.23	-0.81
Q7_8	217	3.92	0.84	-0.44	0.07
Q7_9	217	3.75	0.82	-0.16	-0.54
Q7_10	217	4.00	0.89	-0.57	-0.25
Q7_11	217	3.94	0.85	-0.32	-0.67
Q7_12	217	4.13	0.75	-0.48	-0.32
Q7_13	217	3.80	0.84	-0.17	-0.64
Q7_14	217	3.80	0.87	-0.16	-0.79
Q7_15	217	3.94	0.92	-0.54	-0.40
Q7_16	217	4.16	0.84	-0.63	-0.47
Q8_1	217	3.96	0.84	-0.52	-0.06
Q8_2	217	3.83	0.85	-0.33	-0.51
Q8_3	217	3.76	0.96	-0.30	-0.58
Q8_4	217	3.80	0.92	-0.48	-0.22
Q8_5	217	4.03	0.83	-0.54	-0.08
Q8_6	217	3.69	0.91	-0.21	-0.76
Q8_7	217	3.46	1.03	-0.26	-0.48
Q8_8	217	3.65	0.93	-0.26	-0.45
Q8_9	217	3.63	0.88	0.03	-0.78
Q8_10	217	3.78	0.87	-0.22	-0.48
Q9_1	217	3.98	0.85	-0.57	0.18
Q9_2	217	3.96	0.85	-0.60	0.28
Q9_3	217	4.00	0.81	-0.50	-0.00
Q9_4	217	3.91	0.80	-0.21	-0.61
Q9_5	217	4.03	0.83	-0.48	-0.19
Q9_6	217	3.72	0.89	-0.36	-0.38
Q9_7	217	4.12	0.81	-0.69	0.26
Q9_8	217	3.78	0.81	-0.14	-0.31
Q9_9	217	3.41	1.05	-0.21	-0.64
Q9_10	217	3.62	0.99	-0.42	-0.19
Q9_11	217	3.85	0.90	-0.31	-0.55
Q9_12	217	3.29	1.16	-0.16	-0.87
Q9_13	217	3.70	1.02	-0.42	-0.52

Q9_14	217	3.97	0.87	-0.43	-0.44
Q9_15	217	3.72	0.92	-0.37	-0.16

Table 15. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q9_16	217	3.48	1.09	-0.15	-0.90
Q9_17	217	3.67	0.98	-0.35	-0.50
Q9_18	217	3.80	0.86	-0.19	-0.72
Q9_19	217	3.38	1.01	-0.11	-0.64
Q9_20	217	3.59	0.96	-0.30	-0.19
Q9_21	217	3.62	0.98	-0.27	-0.58
Q9_22	217	3.73	0.93	-0.37	-0.36
Q9_23	217	4.02	0.92	-0.84	0.60
Q10_1	217	3.57	0.93	-0.12	-0.69
Q10_2	217	3.81	0.85	-0.33	-0.28
Q10_3	217	3.82	0.86	-0.34	-0.49
Q10_4	217	3.59	0.97	-0.15	-0.83
Q10_5	217	3.48	1.00	-0.17	-0.74
Q10_6	217	3.34	1.19	-0.21	-0.83
Q10_7	217	3.45	1.06	-0.24	-0.66
Q11_1	217	4.06	0.99	-0.78	-0.10
Q11_2	217	4.23	0.88	-0.95	0.21
Q11_3	217	4.22	0.88	-0.95	0.10
Q11_4	217	4.32	0.81	-1.05	0.70
Q11_5	217	4.47	0.79	-1.43	1.29
Q11_6	217	4.02	0.88	-0.53	-0.36
Q11_7	217	3.93	0.97	-0.45	-0.73
Q11_8	217	4.11	0.86	-0.73	0.07
Q11_9	217	3.81	0.99	-0.41	-0.61
Q11_10	217	3.94	0.96	-0.58	-0.47
Q11_11	217	4.07	0.98	-0.81	-0.27
Q12_1	217	3.82	0.95	-0.50	-0.19
Q12_2	217	3.62	1.05	-0.45	-0.49
Q12_3	217	3.66	0.97	-0.28	-0.62
Q12_4	217	3.68	1.01	-0.42	-0.58
Q12_5	217	3.37	1.06	-0.27	-0.68
Q12_6	217	3.55	1.01	-0.46	-0.23
Q12_7	217	3.57	0.97	-0.41	-0.36
Q13_1	217	3.71	0.99	-0.38	-0.53
Q13_2	217	3.45	1.15	-0.24	-0.86
Q13_3	217	3.66	0.99	-0.47	-0.35
Q13_4	217	3.46	1.12	-0.19	-0.77
Q13_5	217	3.56	1.01	-0.42	-0.34

Q13_6	217	3.63	1.06	-0.54	-0.18
Q13_7	217	3.52	1.19	-0.52	-0.56

Table 15. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q14_1	217	4.02	0.93	-0.80	0.30
Q14_2	217	4.10	0.95	-1.03	0.92
Q14_3	217	3.82	1.03	-0.64	-0.08
Q14_4	217	3.96	0.94	-0.80	0.40
Q14_5	217	4.18	0.95	-1.07	0.62
Q14_6	217	4.16	0.90	-0.92	0.42
Q14_7	217	3.96	1.03	-0.92	0.46
Q14_8	217	4.24	0.93	-1.18	0.95
Q14_9	217	4.27	0.77	-0.68	-0.41
Q14_10	217	4.34	0.84	-1.16	0.85
Q14_11	217	3.68	1.02	-0.38	-0.45
Q14_12	217	4.19	0.91	-0.93	0.45
Q14_13	217	3.95	1.00	-0.68	-0.23
Q14_14	217	3.85	0.95	-0.53	-0.16
Q14_15	217	3.79	1.01	-0.46	-0.31
Q15_1	217	3.29	0.98	-0.08	-0.29
Q15_2	217	3.09	1.07	-0.00	-0.62
Q15_3	217	3.09	1.13	-0.09	-0.85
Q15_4	217	3.29	1.09	-0.22	-0.66
Q15_5	217	3.54	1.07	-0.47	-0.32
Q16_1	217	4.03	0.89	-0.63	-0.01
Q16_2	217	3.97	0.91	-0.59	0.03
Q16_3	217	3.89	0.99	-0.73	0.12
Q16_4	217	3.38	1.02	-0.11	-0.68
Q16_5	217	3.52	1.03	-0.36	-0.40
Q16_6	217	3.68	0.90	-0.36	0.11
Q16_7	217	3.66	1.01	-0.46	-0.34
Q16_8	217	3.67	0.97	-0.43	-0.15
Q16_9	217	3.56	1.04	-0.39	-0.35
Q16_10	217	3.47	1.09	-0.36	-0.49
Q16_11	217	3.06	1.06	0.02	-0.57
Q16_12	217	3.08	1.13	-0.07	-0.76
Q16_13	217	3.28	1.16	-0.05	-0.92

Table 16. Descriptive Statistics for Sample 2

	N	*Mean*	*SD*	Skewness	Kurtosis
Q1_1	217	4.31	0.72	-0.99	1.44
Q1_2	217	3.92	0.76	-0.35	-0.19
Q1_3	217	4.24	0.77	-0.81	0.51
Q1_4	217	4.18	0.83	-0.74	0.10
Q1_5	217	4.00	0.84	-0.41	-0.59
Q1_6	217	4.04	0.76	-0.25	-0.74
Q1_7	217	3.95	0.86	-0.43	-0.35
Q1_8	217	4.27	0.80	-0.90	0.45
Q1_9	217	4.00	0.82	-0.40	-0.53
Q1_10	217	3.84	0.87	-0.27	-0.67
Q1_11	217	3.79	0.82	-0.14	-0.61
Q1_12	217	4.03	0.87	-0.52	-0.53
Q1_13	217	4.24	0.90	-0.98	0.23
Q1_14	217	3.83	0.81	-0.09	-0.74
Q2_1	217	3.41	0.91	-0.07	-0.52
Q2_2	217	3.81	0.85	-0.24	-0.42
Q2_3	217	3.48	0.90	0.04	-0.76
Q2_4	217	3.77	0.79	-0.11	-0.51
Q2_5	217	3.88	0.85	-0.30	-0.64
Q2_6	217	3.94	0.74	-0.17	-0.56
Q2_7	217	3.95	0.88	-0.55	-0.37
Q2_8	217	4.03	0.79	-0.39	-0.45
Q2_9	217	3.54	0.97	-0.06	-0.71
Q2_10	217	4.42	0.80	-1.23	0.68
Q2_11	217	4.14	0.79	-0.59	0.01
Q2_12	217	3.66	0.93	-0.21	-0.48
Q2_13	217	3.82	0.84	-0.39	-0.37
Q2_14	217	4.11	0.77	-0.49	-0.31
Q3_1	217	3.81	0.86	-0.32	-0.33
Q3_2	217	4.24	0.70	-0.52	-0.25
Q3_3	217	3.66	0.93	-0.14	-0.68
Q3_4	217	3.82	0.90	-0.37	-0.43
Q3_5	217	3.82	0.88	-0.14	-0.88
Q3_6	217	3.85	0.84	-0.26	-0.61
Q3_7	217	4.04	0.81	-0.54	0.05
Q3_8	217	4.06	0.77	-0.34	-0.62
Q3_9	217	4.00	0.80	-0.27	-0.79
Q4_1	217	4.00	0.81	-0.37	-0.56
Q4_2	217	4.01	0.85	-0.64	0.29
Q4_3	217	4.11	0.71	-0.39	-0.25
Q4_4	217	4.08	0.79	-0.54	-0.23
Q4_5	217	4.09	0.74	-0.41	-0.35

Table 16. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q4_6	217	4.02	0.81	-0.45	-0.39
Q4_7	217	4.20	0.69	-0.37	-0.57
Q4_8	217	3.95	0.79	-0.30	-0.50
Q4_9	217	4.06	0.78	-0.39	-0.48
Q4_10	217	3.98	0.76	-0.22	-0.63
Q4_11	217	3.98	0.87	-0.54	-0.39
Q4_12	217	3.53	1.01	-0.01	-0.89
Q4_13	217	3.96	0.78	-0.17	-0.78
Q4_14	217	3.90	0.92	-0.32	-0.89
Q4_15	217	4.00	0.79	-0.34	-0.56
Q4_16	217	3.82	0.84	-0.16	-0.49
Q4_17	217	3.98	0.83	-0.34	-0.63
Q5_1	217	3.80	0.87	-0.19	-0.54
Q5_2	217	3.75	0.89	-0.18	-0.78
Q5_3	217	3.87	0.90	-0.38	-0.48
Q5_4	217	3.92	0.95	-0.67	0.01
Q5_5	217	3.92	0.90	-0.52	-0.32
Q5_6	217	3.89	0.89	-0.45	-0.34
Q5_7	217	3.89	0.89	-0.26	-0.69
Q5_8	217	3.70	1.00	-0.38	-0.46
Q5_9	217	3.68	1.05	-0.38	-0.67
Q5_10	217	3.65	0.99	-0.43	-0.38
Q5_11	217	3.70	0.95	-0.28	-0.69
Q6_1	217	4.10	0.85	-0.82	0.42
Q6_2	217	4.24	0.80	-0.72	-0.34
Q6_3	217	3.75	0.89	-0.19	-0.73
Q6_4	217	3.91	0.88	-0.55	0.06
Q6_5	217	3.81	0.94	-0.37	-0.61
Q6_6	217	3.92	0.89	-0.27	-0.92
Q6_7	217	4.07	0.87	-0.64	-0.37
Q6_8	217	4.28	0.79	-0.99	0.81
Q6_9	217	4.11	0.81	-0.45	-0.66
Q6_10	217	4.04	0.86	-0.42	-0.79
Q6_11	217	4.08	0.87	-0.53	-0.68
Q6_12	217	4.10	0.93	-0.70	-0.20
Q7_1	217	4.00	0.78	-0.22	-0.77
Q7_2	217	4.19	0.81	-0.57	-0.64
Q7_3	217	3.42	1.00	0.07	-0.83
Q7_4	217	3.72	0.91	-0.28	-0.57
Q7_5	217	3.88	0.93	-0.40	-0.58
Q7_6	217	3.55	1.14	-0.48	-0.55
Q7_7	217	3.85	0.91	-0.46	-0.22

Table 16. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q7_8	217	3.95	0.88	-0.44	-0.40
Q7_9	217	3.77	0.91	-0.26	-0.76
Q7_10	217	4.07	0.93	-0.77	0.19
Q7_11	217	4.16	0.83	-0.64	-0.42
Q7_12	217	4.13	0.80	-0.72	0.36
Q7_13	217	3.97	0.83	-0.48	-0.32
Q7_14	217	3.82	0.82	-0.01	-0.89
Q7_15	217	4.01	0.91	-0.46	-0.63
Q7_16	217	4.25	0.88	-1.04	0.48
Q8_1	217	4.15	0.81	-0.69	-0.10
Q8_2	217	4.02	0.82	-0.52	-0.03
Q8_3	217	3.91	0.93	-0.42	-0.61
Q8_4	217	3.87	0.95	-0.40	-0.68
Q8_5	217	4.08	0.82	-0.50	-0.48
Q8_6	217	3.69	0.92	-0.25	-0.30
Q8_7	217	3.52	1.05	-0.09	-0.91
Q8_8	217	3.85	0.93	-0.52	-0.22
Q8_9	217	3.76	0.85	-0.14	-0.69
Q8_10	217	3.87	0.89	-0.37	-0.64
Q9_1	217	4.08	0.84	-0.53	-0.50
Q9_2	217	4.04	0.82	-0.51	-0.35
Q9_3	217	4.10	0.79	-0.40	-0.73
Q9_4	217	3.97	0.87	-0.45	-0.36
Q9_5	217	4.13	0.81	-0.55	-0.45
Q9_6	217	3.61	1.00	-0.38	-0.25
Q9_7	217	4.08	0.82	-0.64	0.13
Q9_8	217	3.81	0.91	-0.38	-0.32
Q9_9	217	3.33	1.06	-0.18	-0.48
Q9_10	217	3.62	0.92	-0.23	-0.44
Q9_11	217	3.94	0.95	-0.59	-0.28
Q9_12	217	3.18	1.18	-0.12	-0.82
Q9_13	217	3.81	0.98	-0.51	-0.23
Q9_14	217	3.94	0.91	-0.46	-0.30
Q9_15	217	3.63	0.98	-0.29	-0.56
Q9_16	217	3.42	1.07	-0.12	-0.80
Q9_17	217	3.74	0.96	-0.48	-0.28
Q9_18	217	3.75	0.94	-0.40	-0.28
Q9_19	217	3.41	0.99	-0.00	-0.84
Q9_20	217	3.68	0.90	-0.49	0.19
Q9_21	217	3.73	1.00	-0.36	-0.68
Q9_22	217	3.86	0.91	-0.44	-0.27
Q9_23	217	4.13	0.86	-0.55	-0.73

Table 16. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q10_1	217	3.57	0.94	-0.19	-0.57
Q10_2	217	3.89	0.82	-0.30	-0.50
Q10_3	217	3.88	0.81	-0.50	0.45
Q10_4	217	3.59	1.01	-0.30	-0.56
Q10_5	217	3.55	0.99	-0.30	-0.53
Q10_6	217	3.33	1.11	-0.17	-0.68
Q10_7	217	3.39	0.99	-0.12	-0.43
Q11_1	217	4.10	0.88	-0.60	-0.55
Q11_2	217	4.16	0.85	-0.72	-0.27
Q11_3	217	4.31	0.76	-0.78	-0.24
Q11_4	217	4.28	0.85	-1.06	0.66
Q11_5	217	4.41	0.83	-1.19	0.38
Q11_6	217	3.98	0.90	-0.48	-0.48
Q11_7	217	3.97	0.95	-0.59	-0.31
Q11_8	217	4.06	0.91	-0.67	-0.26
Q11_9	217	3.78	0.88	-0.29	-0.62
Q11_10	217	3.95	0.84	-0.41	-0.50
Q11_11	217	4.09	0.88	-0.50	-0.79
Q12_1	217	4.01	0.83	-0.58	0.06
Q12_2	217	3.69	0.93	-0.34	-0.40
Q12_3	217	3.66	0.91	-0.25	-0.56
Q12_4	217	3.81	1.00	-0.66	-0.04
Q12_5	217	3.53	1.11	-0.29	-0.78
Q12_6	217	3.64	1.03	-0.43	-0.36
Q12_7	217	3.65	1.01	-0.37	-0.42
Q13_1	217	3.82	0.95	-0.32	-0.71
Q13_2	217	3.48	1.01	-0.17	-0.67
Q13_3	217	3.72	0.95	-0.35	-0.48
Q13_4	217	3.50	1.01	-0.15	-0.78
Q13_5	217	3.52	0.97	-0.10	-0.71
Q13_6	217	3.50	0.97	-0.10	-0.46
Q13_7	217	3.42	1.13	-0.28	-0.74
Q14_1	217	4.04	0.88	-0.51	-0.63
Q14_2	217	4.14	0.87	-0.82	0.34
Q14_3	217	3.88	0.94	-0.42	-0.47
Q14_4	217	3.94	0.92	-0.48	-0.50
Q14_5	217	4.26	0.83	-0.89	0.02
Q14_6	217	4.21	0.86	-0.93	0.39
Q14_7	217	4.02	0.99	-0.80	-0.02
Q14_8	217	4.31	0.81	-0.94	0.02
Q14_9	217	4.31	0.81	-0.98	0.22
Q14_10	217	4.39	0.78	-1.15	0.74

Table 16. (continued)

	N	*Mean*	*SD*	Skewness	Kurtosis
Q14_11	217	3.75	0.98	-0.39	-0.69
Q14_12	217	4.29	0.78	-0.86	0.04
Q14_13	217	4.00	0.88	-0.49	-0.58
Q14_14	217	3.91	0.92	-0.38	-0.62
Q14_15	217	3.86	0.92	-0.45	-0.13
Q15_1	217	3.27	1.04	-0.19	-0.59
Q15_2	217	3.14	1.17	-0.18	-0.87
Q15_3	217	3.24	1.14	-0.17	-0.81
Q15_4	217	3.37	1.06	-0.26	-0.50
Q15_5	217	3.54	1.03	-0.32	-0.38
Q16_1	217	4.13	0.80	-0.72	0.37
Q16_2	217	4.12	0.81	-0.78	0.78
Q16_3	217	4.08	0.83	-0.76	0.64
Q16_4	217	3.42	1.09	-0.22	-0.65
Q16_5	217	3.72	0.96	-0.41	-0.35
Q16_6	217	3.81	0.92	-0.48	-0.23
Q16_7	217	3.71	0.94	-0.37	-0.31
Q16_8	217	3.61	0.98	-0.40	-0.28
Q16_9	217	3.52	0.98	-0.22	-0.61
Q16_10	217	3.53	1.03	-0.29	-0.62
Q16_11	217	3.16	1.12	-0.01	-0.71
Q16_12	217	3.10	1.15	-0.08	-0.72
Q16_13	217	3.27	1.11	-0.14	-0.66

APPENDIX F. NULL ANOVA RESULTS

Gender.

Table 16. Descriptive Statistics for Students of Different Genders

	Male (*n*=282) *Mean (SD)*	Female (*n*=146) *Mean (SD)*
F1	3.53 (0.86)	3.61 (0.89)
F3	4.02 (0.77)	4.14 (0.76)

Table 17. Levene's Test for Students of Different Genders

	Levene's test	*p*
F1	1.70	.19
F3	0.30	.40

Table 18. ANOVA for Students of Different Genders

	F	*p*
F1	0.78	.38
F3	2.09	.15

Degree.

Table 19. Descriptive Statistics for Students Pursuing Different Degrees

	BS (*n*=365) *Mean (SD)*	MS (*n*=69) *Mean (SD)*
F1	3.60 (0.84)	3.36 (0.97)
F2	3.78 (0.73)	3.80 (0.81)
F3	4.06 (0.79)	4.04 (0.71)
F4	3.27 (0.92)	3.28 (0.96)

Table 20. Levene’s Test for Students Pursuing Different Degrees

	Levene's test	*p*
F1	3.81	.05
F2	1.79	.18
F3	0.56	.46
F4	0.65	.42

Table 21. ANOVA for Students Pursuing Different Degrees

	F	*p*
F1	4.26	0.04
F2	0.03	0.87
F3	0.04	0.84
F4	0.01	0.92

Table 22. Welch's Test for Students Pursuing Different Degrees

	F	*p*
F1	3.52	0.06

Discipline.

Table 23. Descriptive Statistics for Students in Different Disciplines

	AAE-1 (*n*=86)	ABE-2 (*n*=22)	BME-3 (*n*=38)	ChE-4 (*n*=23)	CE-5 (*n*=45)	ECE-7 (*n*=104)	IE-10 (*n*=27)	ME-12 (*n*=56)	Other-14 (*n*=33)
F1	3.34 (0.91)	3.79 (0.76)	3.35 (0.80)	3.77 (0.77)	3.51 (0.76)	3.52 (0.89)	3.90 (0.95)	3.62 (0.74)	3.91 (0.99)
F2	3.91 (0.72)	3.53 (0.67)	3.50 (0.85)	3.66 (0.74)	3.52 (0.68)	4.03 (0.66)	3.98 (0.60)	3.73 (0.80)	3.54 (0.71)
F3	4.06 (0.80)	4.15 (0.76)	4.02 (0.76)	4.36 (0.66)	4.04 (0.67)	3.90 (0.83)	4.40 (0.64)	3.99 (0.78)	4.18 (0.73)
F4	3.12 (0.92)	3.19 (0.88)	2.87 (0.86)	3.21 (0.80)	3.22 (0.94)	3.40 (0.92)	3.80 (0.74)	3.52 (0.87)	3.03 (1.02)

Note: Others include: CEM, ENE, EEE, MSE, NE

Table 24. Levene's test for Students in Different Disciplines

	Levene's test	*p*
F1	1.24	0.27
F2	1.67	0.10
F3	0.53	0.84
F4	0.81	0.60

Table 25. ANOVA for Students in Different Disciplines

	F	*p*
F1	2.73	0.01
F2	4.58	0.00
F3	1.85	0.07
F4	3.59	0.00

Table 26. Post hoc Turkey Test on F1 (sustainability and societal impact) for Students in Different Disciplines

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Society (F1)	1	2	-0.45	0.20	0.40	-1.09	0.18
		3	-0.02	0.17	1.00	-0.53	0.50
		4	-0.44	0.20	0.42	-1.06	0.19
		5	-0.17	0.16	0.97	-0.66	0.32
		7	-0.18	0.12	0.87	-0.57	0.20
		10	-0.57	0.19	0.07	-1.16	0.02
		12	-0.28	0.15	0.60	-0.74	0.17
		14	-0.57*	0.17	0.03	-1.12	-0.03
	2	1	0.45	0.20	0.40	-0.18	1.09
		3	0.44	0.23	0.61	-0.28	1.15
		4	0.02	0.25	1.00	-0.78	0.81
		5	0.28	0.22	0.94	-0.41	0.97
		7	0.27	0.20	0.92	-0.36	0.89
		10	-0.12	0.25	1.00	-0.88	0.65
		12	0.17	0.21	1.00	-0.50	0.84
		14	-0.12	0.24	1.00	-0.86	0.61
	3	1	0.02	0.17	1.00	-0.50	0.53
		2	-0.44	0.23	0.61	-1.15	0.28
		4	-0.42	0.23	0.64	-1.12	0.28
		5	-0.16	0.19	1.00	-0.74	0.43
		7	-0.17	0.16	0.98	-0.67	0.34
		10	-0.55	0.21	0.20	-1.22	0.12
		12	-0.27	0.18	0.86	-0.83	0.29
		14	-0.56	0.20	0.13	-1.19	0.07
	4	1	0.44	0.20	0.42	-0.19	1.06
		2	-0.02	0.25	1.00	-0.81	0.78
		3	0.42	0.23	0.64	-0.28	1.12
		5	0.26	0.22	0.95	-0.42	0.95
		7	0.25	0.20	0.93	-0.36	0.87
		10	-0.13	0.24	1.00	-0.89	0.62
		12	0.15	0.21	1.00	-0.51	0.81
		14	-0.14	0.23	1.00	-0.86	0.58
	5	1	0.17	0.16	0.97	-0.32	0.66
		2	-0.28	0.22	0.94	-0.97	0.41
		3	0.16	0.19	1.00	-0.43	0.74
		4	-0.26	0.22	0.95	-0.95	0.42

Table 26. (continued)

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Society (F1)	5	7	-0.01	0.15	1.00	-0.49	0.46
		10	-0.40	0.21	0.61	-1.04	0.25
		12	-0.11	0.17	1.00	-0.64	0.42
		14	-0.40	0.20	0.50	-1.01	0.21
	7	1	0.18	0.12	0.87	-0.20	0.57
		2	-0.27	0.20	0.92	-0.89	0.36
		3	0.17	0.16	0.98	-0.34	0.67
		4	-0.25	0.20	0.93	-0.87	0.36
		5	0.01	0.15	1.00	-0.46	0.49
		10	-0.39	0.18	0.48	-0.96	0.19
		12	-0.10	0.14	1.00	-0.54	0.34
		14	-0.39	0.17	0.34	-0.92	0.14
	10	1	0.57	0.19	0.07	-0.02	1.16
		2	0.12	0.25	1.00	-0.65	0.88
		3	0.55	0.21	0.20	-0.12	1.22
		4	0.13	0.24	1.00	-0.62	0.89
		5	0.40	0.21	0.61	-0.25	1.04
		7	0.39	0.18	0.48	-0.19	0.96
		12	0.29	0.20	0.89	-0.34	0.91
		14	-0.01	0.22	1.00	-0.70	0.68
	12	1	0.28	0.15	0.60	-0.17	0.74
		2	-0.17	0.21	1.00	-0.84	0.50
		3	0.27	0.18	0.86	-0.29	0.83
		4	-0.15	0.21	1.00	-0.81	0.51
		5	0.11	0.17	1.00	-0.42	0.64
		7	0.10	0.14	1.00	-0.34	0.54
		10	-0.29	0.20	0.89	-0.91	0.34
		14	-0.29	0.19	0.82	-0.88	0.29
	14	1	0.57*	0.17	0.03	0.03	1.12
		2	0.12	0.24	1.00	-0.61	0.86
		3	0.56	0.20	0.13	-0.07	1.19
		4	0.14	0.23	1.00	-0.58	0.86
		5	0.40	0.20	0.50	-0.21	1.01
		7	0.39	0.17	0.34	-0.14	0.92
		10	0.01	0.22	1.00	-0.68	0.70
		12	0.29	0.19	0.82	-0.29	0.88

Table 27. Post hoc Turkey Test on F2 (tools) for Students in Different Disciplines

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Tool (F2)	1	2	0.38	0.17	0.38	-0.15	0.92
		3	0.41	0.14	0.08	-0.02	0.85
		4	0.25	0.17	0.85	-0.27	0.78
		5	0.39	0.13	0.08	-0.02	0.80
		7	-0.12	0.10	0.96	-0.45	0.21
		10	-0.07	0.16	1.00	-0.57	0.42
		12	0.18	0.12	0.86	-0.20	0.57
		14	0.37	0.15	0.22	-0.09	0.83
	2	1	-0.38	0.17	0.38	-0.92	0.15
		3	0.03	0.19	1.00	-0.57	0.63
		4	-0.13	0.21	1.00	-0.80	0.54
		5	0.00	0.19	1.00	-0.58	0.59
		7	-0.50	0.17	0.07	-1.03	0.02
		10	-0.46	0.21	0.39	-1.10	0.18
		12	-0.20	0.18	0.97	-0.77	0.36
		14	-0.02	0.20	1.00	-0.63	0.60
	3	1	-0.41	0.14	0.08	-0.85	0.02
		2	-0.03	0.19	1.00	-0.63	0.57
		4	-0.16	0.19	0.99	-0.75	0.43
		5	-0.03	0.16	1.00	-0.52	0.47
		7	-0.53*	0.14	0.00	-0.96	-0.11
		10	-0.49	0.18	0.15	-1.05	0.08
		12	-0.23	0.15	0.8	-0.70	0.24
		14	-0.04	0.17	1.000	-0.58	0.49
	4	1	-0.25	0.17	0.84	-0.78	0.27
		2	0.13	0.21	1.00	-0.54	0.80
		3	0.16	0.19	0.96	-0.43	0.75
		5	0.13	0.18	0.99	-0.44	0.71
		7	-0.37	0.17	0.37	-0.89	0.14
		10	-0.33	0.20	0.80	-0.96	0.31
		12	-0.07	0.18	1.00	-0.63	0.48
		14	0.12	0.20	1.00	-0.49	0.72
	5	1	-0.39	0.13	0.08	-0.80	0.02
		2	0.00	0.19	1.00	-0.59	0.58
		3	0.03	0.16	1.00	-0.47	0.52
		4	-0.13	0.18	0.99	-0.71	0.44
		7	-0.51*	0.13	0.00	-0.91	-0.11
		10	-0.46	0.17	0.17	-1.01	0.08

Table 27. (continued)

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Tool (F2)	5	12	-0.20	0.14	0.89	-0.65	0.24
		14	-0.02	0.16	1.00	-0.53	0.50
	7	1	0.12	0.10	0.96	-0.21	0.45
		2	0.50	0.17	0.07	-0.02	1.03
		3	0.53*	0.14	0.00	0.11	0.96
		4	0.37	0.17	0.37	-0.14	0.89
		5	0.51*	0.13	0.00	0.11	0.91
		10	0.05	0.16	1.00	-0.44	0.53
		12	0.30	0.12	0.21	-0.07	0.67
		14	0.49*	0.14	0.02	0.04	0.94
	10	1	0.07	0.16	1.00	-0.42	0.57
		2	0.46	0.21	0.39	-0.18	1.10
		3	0.49	0.18	0.15	-0.08	1.05
		4	0.33	0.20	0.80	-0.31	0.96
		5	0.46	0.17	0.17	-0.08	1.01
		7	-0.05	0.16	1.00	-0.53	0.44
		12	0.26	0.17	0.84	-0.27	0.78
		14	0.44	0.19	0.29	-0.14	1.03
	12	1	-0.18	0.12	0.86	-0.57	0.20
		2	0.20	0.18	0.97	-0.36	0.77
		3	0.23	0.15	0.84	-0.24	0.70
		4	0.07	0.18	1.00	-0.48	0.63
		5	0.20	0.14	0.89	-0.24	0.65
		7	-0.30	0.12	0.21	-0.67	0.07
		10	-0.26	0.17	0.84	-0.78	0.27
		14	0.19	0.16	0.96	-0.31	0.68
	14	1	-0.37	0.15	0.22	-0.83	0.09
		2	0.02	0.20	1.00	-0.60	0.63
		3	0.04	0.17	1.00	-0.49	0.58
		4	-0.12	0.20	1.00	-0.72	0.49
		5	0.02	0.16	1.00	-0.50	0.53
		7	-0.49*	0.14	0.02	-0.94	-0.04
		10	-0.44	0.19	0.29	-1.03	0.14
		12	-0.19	0.16	0.96	-0.68	0.31

* $p<0.05$ (α level for Holm-Bonferroni correction) For group 5 (CE) and group 7 (ECE) α level=0.00138, so the difference of the mean is not significant; for group 3 (BME) and group 7 (ECE) α level=0.00138, so the difference of the mean is not significant.

Table 28. Post hoc Turkey Test on F3 (health and safety) for Students in Different Disciplines

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Safety (F3)	1	2	-0.10	0.18	1.00	-0.67	0.48
		3	0.04	0.15	1.00	-0.43	0.51
		4	-0.30	0.18	0.75	-0.87	0.26
		5	0.02	0.14	1.00	-0.42	0.46
		7	0.15	0.11	0.91	-0.20	0.50
		10	-0.34	0.17	0.54	-0.87	0.19
		12	0.07	0.13	1.00	-0.34	0.48
		14	-0.13	0.16	0.99	-0.62	0.36
	2	1	0.10	0.18	1.00	-0.48	0.67
		3	0.14	0.21	0.99	-0.50	0.78
		4	-0.21	0.23	0.99	-0.92	0.50
		5	0.11	0.20	1.00	-0.51	0.73
		7	0.25	0.18	0.90	-0.31	0.81
		10	-0.24	0.22	0.97	-0.93	0.44
		12	0.16	0.19	0.99	-0.44	0.76
		14	-0.03	0.21	1.00	-0.69	0.63
	3	1	-0.04	0.15	1.00	-0.51	0.43
		2	-0.14	0.21	0.99	-0.78	0.50
		4	-0.34	0.20	0.74	-0.98	0.29
		5	-0.02	0.17	1.00	-0.55	0.50
		7	0.11	0.15	0.99	-0.34	0.57
		10	-0.38	0.19	0.56	-0.98	0.22
		12	0.03	0.16	1.00	-0.48	0.53
		14	-0.17	0.18	0.99	-0.74	0.40
	4	1	0.30	0.18	0.75	-0.26	0.87
		2	0.21	0.23	0.99	-0.50	0.92
		3	0.34	0.20	0.74	-0.29	0.98
		5	0.32	0.20	0.78	-0.29	0.93
		7	0.46	0.18	0.19	-0.09	1.01
		10	-0.04	0.22	1.0	-0.71	0.64
		12	0.37	0.19	0.58	-0.22	0.96
		14	0.18	0.21	0.99	-0.47	0.83
	5	1	-0.02	0.14	1.00	-0.46	0.42
		2	-0.11	0.20	1.00	-0.73	0.51
		3	0.02	0.17	1.00	-0.50	0.55
		4	-0.32	0.20	0.78	-0.93	0.29

Table 28. (continued)

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Safety (F3)	5	7	0.14	0.14	0.98	-0.29	0.56
		10	-0.36	0.19	0.61	-0.94	0.23
		12	0.05	0.15	1.00	-0.43	0.53
		14	-0.14	0.18	0.99	-0.69	0.40
	7	1	-0.15	0.11	0.91	-0.50	0.20
		2	-0.25	0.18	0.90	-0.81	0.31
		3	-0.11	0.15	0.99	-0.57	0.34
		4	-0.46	0.18	0.19	-1.01	0.09
		5	-0.14	0.14	0.98	-0.56	0.29
		10	-0.49	0.17	0.07	-1.01	0.02
		12	-0.09	0.13	0.99	-0.48	0.31
		14	-0.28	0.15	0.66	-0.76	0.20
	10	1	0.34	0.17	0.54	-0.19	0.87
		2	0.24	0.22	0.97	-0.44	0.93
		3	0.38	0.19	0.56	-0.22	0.98
		4	0.04	0.22	1.00	-0.64	0.71
		5	0.36	0.19	0.61	-0.23	0.94
		7	0.49	0.17	0.07	-0.02	1.01
		12	0.41	0.18	0.37	-0.15	0.97
		14	0.21	0.20	0.97	-0.41	0.83
	12	1	-0.07	0.13	1.00	-0.48	0.34
		2	-0.16	0.19	0.99	-0.76	0.44
		3	-0.03	0.16	1.00	-0.53	0.48
		4	-0.37	0.19	0.58	-0.96	0.22
		5	-0.05	0.15	1.00	-0.53	0.43
		7	0.09	0.13	0.99	-0.31	0.48
		10	-0.41	0.18	0.37	-0.97	0.15
		14	-0.19	0.17	0.96	-0.72	0.33
	14	1	0.13	0.16	0.99	-0.36	0.62
		2	0.03	0.21	1.00	-0.63	0.69
		3	0.17	0.18	0.99	-0.40	0.74
		4	-0.18	0.21	0.99	-0.83	0.47
		5	0.14	0.18	0.99	-0.40	0.69
		7	0.28	0.15	0.66	-0.20	0.76
		10	-0.21	0.20	0.97	-0.83	0.41
		12	0.19	0.17	0.96	-0.33	0.72

Table 29. Post hoc Turkey Test on F4 (economics) for Students in Different Disciplines

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Economics (F4)	1	2	-0.07	0.22	1.00	-0.74	0.60
		3	0.25	0.18	0.89	-0.30	0.79
		4	-0.10	0.21	1.00	-0.76	0.56
		5	-0.10	0.17	1.00	-0.62	0.42
		7	-0.28	0.13	0.43	-0.69	0.13
		10	-0.69*	0.20	0.01	-1.31	-0.07
		12	-0.40	0.15	0.18	-0.89	0.08
		14	0.08	0.18	1.00	-0.49	0.66
	2	1	0.07	0.22	1.00	-0.60	0.74
		3	0.32	0.24	0.92	-0.44	1.07
		4	-0.03	0.27	1.00	-0.86	0.81
		5	-0.03	0.23	1.00	-0.76	0.70
		7	-0.21	0.21	0.98	-0.87	0.45
		10	-0.62	0.26	0.29	-1.42	0.19
		12	-0.33	0.23	0.86	-1.04	0.37
		14	0.15	0.25	0.99	-0.62	0.93
	3	1	-0.25	0.18	0.89	-0.79	0.30
		2	-0.32	0.24	0.92	-1.07	0.44
		4	-0.34	0.24	0.88	-1.08	0.40
		5	-0.35	0.20	0.71	-0.96	0.27
		7	-0.53	0.17	0.05	-1.06	0.00
		10	-0.93*	0.23	0.00	-1.64	-0.23
		12	-0.65*	0.19	0.01	-1.24	-0.06
		14	-0.16	0.21	0.99	-0.83	0.50
	4	1	0.10	0.21	1.00	-0.56	0.76
		2	0.03	0.27	1.00	-0.81	0.86
		3	0.34	0.24	0.88	-0.40	1.08
		5	0.00	0.23	1.00	-0.72	0.72
		7	-0.19	0.21	0.99	-0.83	0.46
		10	-0.59	0.26	0.33	-1.39	0.21
		12	-0.31	0.22	0.90	-1.00	0.39
		14	0.18	0.24	0.99	-0.58	0.94
	5	1	0.10	0.17	1.00	-0.42	0.62
		2	0.03	0.23	1.00	-0.70	0.76
		3	0.35	0.20	0.71	-0.27	0.96
		4	0.00	0.23	1.00	-0.72	0.72

Table 29. (continued)

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
		7	-0.18	0.16	0.96	-0.68	0.32
		10	-0.59	0.22	0.15	-1.27	0.10
		12	-0.30	0.18	0.75	-0.87	0.26
		14	0.18	0.21	0.99	-0.46	0.83
	7	1	0.28	0.13	0.43	-0.13	0.69
		2	0.21	0.21	0.98	-0.45	0.87
		3	0.53	0.17	0.05	0.00	1.06
		4	0.19	0.21	0.99	-0.46	0.83
		5	0.18	0.16	0.96	-0.32	0.68
		10	-0.40	0.19	0.49	-1.01	0.20
		12	-0.12	0.15	0.99	-0.59	0.34
		14	0.37	0.18	0.51	-0.19	0.93
	10	1	0.69*	0.20	0.01	0.07	1.31
		2	0.62	0.26	0.29	-0.19	1.42
		3	0.93*	0.23	0.00	0.23	1.64
		4	0.59	0.26	0.33	-0.21	1.39
		5	0.59	0.22	0.15	-0.10	1.27
		7	0.40	0.19	0.49	-0.20	1.01
		12	0.28	0.21	0.91	-0.37	0.94
		14	0.77*	0.23	0.02	0.04	1.50
	12	1	0.40	0.15	0.18	-0.08	0.89
		2	0.33	0.23	0.86	-0.37	1.04
		3	0.65*	0.19	0.01	0.06	1.24
		4	0.31	0.22	0.90	-0.39	1.00
		5	0.30	0.18	0.75	-0.26	0.87
		7	0.12	0.15	0.99	-0.34	0.59
		10	-0.28	0.21	0.91	-0.94	0.37
		14	0.49	0.20	0.25	-0.13	1.10
	14	1	-0.08	0.18	1.00	-0.66	0.49
		2	-0.15	0.25	0.99	-0.93	0.62
		3	0.16	0.21	0.99	-0.50	0.83
		4	-0.18	0.24	0.99	-0.94	0.58
		5	-0.18	0.21	0.99	-0.83	0.46
		7	-0.37	0.18	0.51	-0.93	0.19
		10	-0.77*	0.23	0.02	-1.50	-0.04
		12	-0.49	0.20	0.25	-1.10	0.13

* $p < 0.05$ (α level for Holm-Bonferroni correction)

For group 1 (AAE) and group 10 (IE) α level=0.00143, so the difference of the mean is not significant. For group 3 (BME) and group 10 (IE) α level=0.00138, so the difference of the mean is not significant. For group 3 (BME) and group 12 (ME) α level=0.00147, so the difference of the mean is not significant.

Internship.

Table 30. Descriptive Statistics for Students with Different Numbers of Internship Experience

	0 (n=236)	1 (n=112)	2 (n=50)	3 or more (n=36)
F1	3.61 (0.86)	3.42 (0.90)	3.52 (0.92)	3.74 (0.72)
F2	3.76 (0.75)	3.74 (0.76)	3.76 (0.71)	4.12 (0.65)
F3	4.04 (0.80)	4.08 (0.75)	3.97 (0.78)	4.19 (0.68)
F4	3.25 (0.91)	3.26 (0.90)	3.32 (0.97)	3.36 (1.04)

Table 31. Levene's Test for Students with Different Numbers of Internship Experience

	Levene's test	p
F1	0.63	0.59
F2	0.55	0.65
F3	0.90	0.44
F4	1.05	0.37

Table 32. ANOVA for Students with Different Numbers of Internship Experience

	F	p
F1	1.81	0.15
F2	2.76	0.04
F3	0.65	0.58
F4	0.19	0.90

Table 33. Post hoc Turkey Test on F2 (tools) for Students with Different Numbers of Internship Experience

Number of Engineering Internship		Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	0.02	0.09	1.00	-0.21	0.25
	3	0.00	0.11	1.00	-0.30	0.30
	4	-0.36*	0.12	0.02	-0.69	-0.04
2	1	-0.02	0.09	1.00	-0.25	0.21
	3	-0.02	0.12	1.00	-0.35	0.31
	4	-0.38*	0.13	0.02	-0.73	-0.03
3	1	0.00	0.11	1.00	-0.30	0.30
	2	0.02	0.12	1.00	-0.31	0.35
	4	-0.36	0.15	0.09	-0.76	0.04
4	1	0.36*	0.12	0.02	0.04	0.69
	2	0.38*	0.13	0.02	0.03	0.73
	3	0.36	0.15	0.09	-0.04	0.76

*p<0.05 (α level for Holm-Bonferroni correction)

For 1-4 (0 and 3 ore more) α level=0.0042, so the difference of the mean is not significant.

For 2-4 (1 and 3 or more) α level=0.0045, so the difference of the mean is not significant.

Co-op.

Table 34. Descriptive Statistics for Students with Different Numbers of Co-op Experience

	0 (*n*=371)	1 (*n*=28)	2 (*n*=10)	3 or more (*n*=25)
F1	3.59 (0.87)	3.60 (0.80)	3.22 (1.02)	3.23 (0.72)
F2	3.77 (0.75)	3.88 (0.65)	4.03 (0.59)	3.83 (0.73)
F3	4.07 (0.77)	3.98 (0.87)	4.42 (0.62)	3.90 (0.76)
F4	3.30 (0.92)	3.40 (0.94)	2.89 (0.88)	2.86 (0.83)

Table 35. Levene’s Test for Students with Different Numbers of Co-op Experience

	Levene's test	*p*
F1	0.76	0.52
F2	0.64	0.59
F3	0.21	0.89
F4	0.70	0.55

Table 36. ANOVA for Students with Different Numbers of Co-op Experience

	F	*p*
F1	1.91	0.13
F2	0.59	0.62
F3	1.20	0.31
F4	2.56	0.06

Academic projects.

Table 37. Descriptive Statistics for Students with Different Numbers of Academic Projects

	0 (*n*=32)	1 (*n*=81)	2 (*n*=108)	3 or more (*n*=213)
F1	3.58 (0.78)	3.52 (0.89)	3.59 (0.85)	3.55 (0.88)
F2	3.87 (0.70)	3.71 (0.80)	3.77 (0.70)	3.80 (0.75
F3	3.98 (0.65)	4.03 (0.85)	4.08 (0.76)	4.07 (0.77)
F4	3.51 (0.97)	3.23 (0.96)	3.15 (0.94)	3.31 (0.88)

Table 38. Levene’s Test for Students with Different Numbers of Academic Projects

	Levene's test	*p*
F1	0.73	0.54
F2	0.15	0.93
F3	1.09	0.35
F4	0.32	0.81

Table 39. ANOVA for Students with Different Numbers of Academic Projects

	F	*p*
F1	0.12	0.95
F2	0.49	0.69
F3	0.21	0.89
F4	1.54	0.20

Extracurricular project

Table 40. Descriptive Statistics for Students with Different Numbers of Extracurricular Projects

	0 (*n*=166)	1 (*n*=133)	2 (*n*=64)	3 or more (*n*=72)
F1	3.48 (0.92)	3.57 (0.80)	3.63 (0.83)	3.67 (0.91)
F2	3.63 (0.82)	3.76 (0.64)	3.93 (0.69)	4.04 (0.69)
F3	4.15 (0.73)	3.95 (0.79)	4.03 (0.82)	4.08 (0.77)
F4	3.18 (0.96)	3.31 (0.85)	3.23 (0.94)	3.45 (0.93)

Table 41. Levene's Test for Students with Different Numbers of Extracurricular Projects

	Levene's test	p
F1	1.03	0.38
F2	2.14	0.09
F3	0.37	0.77
F4	0.86	0.46

Table 42. ANOVA for Students with Different Numbers of Extracurricular Projects

	F	*p*
F1	1.00	0.39
F2	6.38	0.00
F3	1.73	0.16
F4	1.58	0.19

Table 43. Post hoc Turkey Test on F2 (tools) for Students with Different Numbers of Extracurricular Projects

Number of Engineering Extracurricular Project		Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-0.14	0.08	0.50	-0.36	0.09
	3	-0.29*	0.11	0.03	-0.58	-0.01
	4	-0.41*	0.10	0.0005	-0.69	-0.14
2	1	0.14	0.08	0.50	-0.09	0.36
	3	-0.16	0.10	0.52	-0.44	0.11
	4	-0.28*	0.10	0.03	-0.54	-0.02
3	1	0.29*	0.11	0.03	0.01	0.58
	2	0.16	0.10	0.52	-0.11	0.44
	4	-0.12	0.12	0.90	-0.43	0.20
4	1	0.41*	0.10	0.001	0.14	0.69
	2	0.28*	0.10	0.03	0.02	0.54
	3	0.12	0.12	0.90	-0.20	0.43

* $p<0.05$ (α level for Holm-Bonferroni correction) For group 1 (no extracurricular engineering projects) and group 3 (two extracurricular engineering projects) α level=0.005, so the difference of the mean is not significant.

For group 1 (no extracurricular engineering projects) and group 4 (three or more extracurricular engineering projects) α level=0.0041, so the difference of the mean is significant. For group 2 (one extracurricular engineering project) and group 4 (three or more extracurricular engineering projects) α level=0.0045, so the difference of the mean is not significant.

Other work experiences.

Table 44. Descriptive Statistics for Students with Different Numbers of Non-Engineering Work Experience

	0 (*n*=99)	1 (*n*=98)	2 (*n*=111)	3 or more (*n*=126)
F1	3.53 (0.86)	3.36 (0.88)	3.60 (0.88)	3.70 (0.88)
F2	3.75 (0.65)	3.70 (0.76)	3.83 (0.78)	3.84 (0.76)
F3	3.96 (0.86)	3.94 (0.77)	4.07 (0.78)	4.22 (0.67)
F4	3.18 (1.05)	3.17 (0.89)	3.24 (0.83)	3.45 (0.90)

Table 45. Levene's Test for Students with Different Numbers of Non-Engineering Work Experience

	Levene's test	*p*
F1	0.45	0.72
F2	0.67	0.57
F3	2.34	0.07
F4	3.63	0.01

Table 46. ANOVA for Students with Different Numbers of Non-Engineering Work Experience

	F	*p*
F1	2.98	0.03
F2	0.86	0.46
F3	3.15	0.02
F4	2.30	0.08

Table 47. Welch's Test for Students with Different Numbers of Non-Engineering Work Experience

	Statistic	*p*
F4	2.28	0.08

Table 48. Post hoc Turkey Test on F1 (sustainability and societal impact) for Students with Different Numbers of Non-Engineering Work Experience

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Society	1	2	0.17	0.12	0.66	-0.16	0.50
		3	-0.07	0.12	0.99	-0.39	0.25
		4	-0.17	0.11	0.60	-0.47	0.14
	2	1	-0.17	0.12	0.66	-0.50	0.16
		3	-0.24	0.12	0.27	-0.56	0.08
		4	-0.34*	0.12	0.02	-0.65	-0.03
	3	1	0.07	0.12	0.99	-0.25	0.39
		2	0.24	0.12	0.27	-0.08	0.56
		4	-0.10	0.11	0.93	-0.40	0.20
	4	1	0.17	0.11	0.60	-0.14	0.47
		2	0.34*	0.12	0.02	0.03	0.65
		3	0.10	0.11	0.93	-0.20	0.40

* p<0.05 (α level for Holm-Bonferroni correction) For group 2 (one other work experience) and group 4 (three or more other work experiences) α level=0.0041, so the difference of the mean is not significant.

Table 49. Post hoc Turkey Test on F3 (health and safety) for Students with Different Numbers of Non-Engineering Work Experience

Dependent Variable			Mean Difference (I-J)	*SE*	*p*	95% Confidence Interval	
						Lower Bound	Upper Bound
Safety	1	2	0.02	0.12	1.00	-0.29	0.33
		3	-0.11	0.11	0.90	-0.42	0.19
		4	-0.26	0.11	0.08	-0.54	0.02
	2	1	-0.02	0.12	1.00	-0.33	0.29
		3	-0.13	0.11	0.76	-0.42	0.15
		4	-0.28*	0.10	0.03	-0.54	-0.02
	3	1	0.11	0.11	0.90	-0.19	0.42
		2	0.13	0.11	0.76	-0.15	0.42
		4	-0.14	0.10	0.5	-0.40	0.11
	4	1	0.26	0.11	0.08	-0.02	0.54
		2	0.28*	0.10	0.03	0.02	0.54
		3	0.14	0.10	0.57	-0.11	0.40

* p<0.05 (α level for Holm-Bonferroni correction) For group 2 (one other work experience) and group 4 (three or more other work experiences) α level=0.0041, so the difference of the mean is not significant.