Fall 2014

The composition of first-year engineering curricula and its relationships to matriculation models and institutional characteristics

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Graduate School ETD Form 9
(Revised 01/14)

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By Xingyu Chen

Entitled
The Composition of First-Year Engineering Curricula and Its Relationships to Matriculation Models and Institutional Characteristics

For the degree of Doctor of Philosophy

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Head of the Department Graduate Program Date

THE COMPOSITION OF FIRST-YEAR ENGINEERING CURRICULA AND ITS RELATIONSHIPS TO MATRICULATION MODELS AND INSTITUTIONAL CHARACTERISTICS

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Xingyu Chen

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2014

Purdue University

West Lafayette, Indiana

This dissertation is dedicated to my family. My parents and my husband Hanjun, thank you for giving me love, encouragement, and support. My lovely little boys Leo and Jason, thank you for giving me joy and keeping me moving forward along the process.

ACKNOWLEDGEMENTS

I would like to thank Dr. Matthew Ohland for his guidance, inspiration, and support throughout my PhD studies.

I would also like to thank the following faculty members who served on my committee: Dr. Phillip Wankat, Dr. Karl Smith, and Dr. Lisa Lattuca. Thanks for their time and efforts spent on this dissertation.

I want to say thank you to Dr. Marrisa Orr and Dr. Catherine Brawner for their guidance on this study and support on related research projects.

I would like to thank Russell Long, Director of Project Assessment in Purdue's School of Engineering Education, for teaching me data management techniques and giving me advice on the problems I encountered during my PhD studies.

I want to thank my supportive graduate friends Xin Chen, Qu Jin, Corey Schimpf, and Daniel Ferguson for their help and support throughout the years.

Finally, I would like to thank my loving husband Hanjun for his support during the process.

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ABSTRACT

Chen, Xingyu. Ph.D., Purdue University, December 2014. The Composition of First-Year Engineering Curricula and Its Relationships to Matriculation Models and Institutional Characteristics. Major Professor: Matthew Ohland.

The preparation of technically excellent and innovative engineering graduates urges for a reform of the engineering curriculum to meet critical challenges in society (National Academy of Engineering, 2005). An examination of the current engineering curricula is needed to offer a baseline to further discuss if the curriculum reform meets the critical challenges. Meanwhile, concern about engineering retention prioritizes a review of the first-year engineering curricula. The existing literature does not include a nationwide examination of the first-year engineering curricula and introductory engineering courses. This study aspired to fill the gap by providing a detail description of the composition of first-year engineering curricula and introductory engineering courses of all ABET EAC-accredited programs. Furthermore, this study investigated the degree to which first-year engineering curricula and institutional characteristics varied by the matriculation policies of engineering programs.

To this end, this study analyzed the recommended first-year course sequences of 1,969 engineering programs and descriptions of 2,222 first-year engineering courses at all 408 U.S. institutions with ABET EAC-accredited programs. Keywords extracted from the engineering course descriptions were classified using a revised First-Year

Engineering Course Classification Scheme (Reid, Reeping, & Spingola, 2013). In addition, institutional characteristics of 408 institutions grouped by matriculation models were examined.

There were five major findings. First, engineering courses took up 14-17% of total credit hours in the first year. Most first-year engineering courses were mandatory instead of elective or optional. Mathematics and science still formed the basis of the early engineering curriculum by accounting for more than half of the first-year credit hours. Second, the composition of first-year engineering curricula, the composition of first-year engineering courses, and the time when the first engineering course was required all varied by matriculation models. Third, topics related to engineering technologies and tools were listed most frequently in first-year engineering course descriptions, followed by topics related to design and the engineering profession. Topics related to global interest were seldom listed. Fourth, while first-year course composition varied by matriculation model, the most frequently listed topics were shared by programs with varied matriculation models, suggesting that content selection of first-year engineering courses was homogenous nationally. Lastly, institutions with different matriculation models had distinct characteristics, demonstrating the existence of relationships between institution-level and unit-level variables shown in the Model of Academic Plans in Context (Lattuca & Stark, 2009).

Findings of this study addressed fundamental questions of engineering education research, and had the potential to help program administrators and instructors with program and curriculum planning purposes.

CHAPTER 1. INTRODUCTION

1.1 Background

In a constantly changing global economy, the United States strives to achieve and maintain a high quality of life, a sustainable environment, economic growth, effective governance, and global competitiveness (Zimmerman & Vanegas, 2007). To achieve these goals, it is critical for the engineering workforce to develop innovative, competitive products and services. The preparation of technically excellent and innovative engineering graduates is at the core of widely discussed education and policy issues (National Academy of Engineering, 2005). As the National Academy of Engineering (NAE) (2004) pointed out, the engineering curriculum should meet the "critical challenges in society" (p. 1) by providing the workforce with relevant skills. Specifically, NAE (2004) urged that engineering education should "reconstitute engineering curricula and related educational programs to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability" (p. 51).

Since late 1980s, government agencies and organizations have made continuous efforts to address the need for engineering curriculum reform. For example, the National Science Foundation (NSF) announced the establishment of the Engineering Education Coalitions (EECs) in 1989 with an aim to design new program structures and curricular content (Coward, Ailes, & Bardon, 2000). Assessment of the coalitions program provided evidence that EECs had supported the revision and development of engineering courses, such as an early introduction of engineering and design elements into the first two years' curriculum at many institutions (Coward, et al., 2000). In 1996, the Accreditation Board for Engineering and Technology (ABET) adopted a new set of criteria – Engineering Criteria 2000 (EC2000), which shifted the basis for accreditation from input-focused to output-focused (Lattuca, Terenzini, & Volkwein, 2006). In addition to addressing the traditional foundational topics, the revised criteria placed particular emphasis on developing professional skills necessary for working in diverse environments, such as communication and teamwork. A research team at Pennsylvania State University assessed the outcomes of the EC2000 criteria and revealed that the criteria had positive impacts on engineering programs and student learning outcomes (Lattuca, et al., 2006). Still, a broad view of what is being taught in the current engineering curricula is needed to offer a baseline to further discuss if the curriculum reform meets the critical challenges.

While the challenges engineers face necessitate an examination of the engineering curricula nationally, concern about engineering retention prioritizes a review of the first-year engineering curricula and introductory engineering courses in particular. Retention in engineering has been a central topic of discussion for engineering education researchers and institution administrators (Bernold, Spurlin, & Anson, 2007; Ohland et al., 2008; Ohland, Yuhasz, & Sill, 2004; Tyson, 2011). Although the persistence rate in engineering is comparable to that in other majors (Ohland, et al., 2008; Seymour & Hewitt, 1997), it remains a significant challenge for engineering schools to retain qualified students, especially underrepresented minorities who are less likely to persist than their White peers (Atman et al., 2010; National Academy of Engineering, 2004; Tsui, 2007). Research on engineering student departure reveals that students are most likely to leave engineering during the third term (Min, Zhang, Long, Anderson, & Ohland, 2011) – the period during which they still have a limited knowledge of the engineering profession (Watson, Pierrakos, & Newbold, 2010). Therefore, it is particularly important to give students significant exposure to the engineering profession in the first year to help dispel perceived misconceptions.

The first-year engineering curriculum is a critical part of the early-stage college experiences in the study of student retention. An effective first-year engineering curriculum not only defines the fundamental knowledge and skills students need to progress to the next level of study, but also affects students' interest in engineering, helps create a sense of belonging, and therefore has an impact on students' decision to pursue an engineering degree (Brawner, Ohland, Chen, & Orr, 2013; Orr, Brawner, Ohland, & Layton, 2013). In particular, introduction to engineering courses offered at the early stage of an engineering curriculum expose students to various aspects of engineering and its disciplines, thus help students either confirm their original choice or identify an engineering subfield of their interests (Brawner, et al., 2013). Based on learning experiences shared by students through interviews, a number of questions about engineering curricula were raised by the National Science Foundation (NSF)-sponsored Center for the Advancement of Engineering Education (CAEE) (Atman, et al., 2010). Specifically, CAEE (Atman, et al., 2010) asked institutions to consider "What is the range of pathways that your students take through your curricula?" (p. 87) "Are there opportunities in the first years of college at your school (such as "introduction to engineering" seminars or courses) that allow students to explore engineering?" (p. 87) "Do they have an accurate and sufficient understanding of the field of engineering and their place in it?" (p. 87) Overall, concern for engineering retention has motivated engineering schools to review their undergraduate engineering curricula with special attention to what students learn in the first year (Ambrose & Amon, 1997).

Given the mission of preparing students to meet the critical challenges and promoting retention particularly in the first year's college study, it is in the interest of engineering educators and engineering program administrators to examine what courses comprise the first-year engineering curricula in various engineering programs across the country, and to figure out what, how, and when the very first engineering concepts are introduced in first-year engineering courses.

1.2 Research Purpose and Research Questions

The purpose of this study was to provide a snapshot of the composition of first-year engineering curricula and to determine its relationships to matriculation models and institutional characteristics. There were two overriding goals of this study. One was to determine what, how, and when "the engineering elements" were introduced through engineering courses in the early-stage of college study. The other was to identify course patterns and institutional characteristics with consideration of variations among matriculation models. Findings of this study would provide engineering administrators with valuable information for program and curriculum planning purposes.

With the stated research purposes, this study took a fresh look at the composition of first-year engineering curricula nationally. To provide a snapshot of the current national first-year engineering curricula, this study analyzed the recommended first-year course sequences and engineering course descriptions of 1,969 unique engineering programs at all 408 U.S. institutions that granted degrees accredited by the ABET Engineering Accreditation Commission (EAC). Curriculum plans and course descriptions in effect during the 2013-14 academic year were collected from university catalogs and departmental websites. This study was concerned with five groups of courses that comprised a typical first-year engineering curriculum: (1) engineering, (2) mathematics, (3) science, (4) computer science, and (5) general education or free electives. Curricular factors that might affect student exposure to engineering were also examined, such as the requirements and schedule of an engineering course. Moreover, this study analyzed the course descriptions of 2,222 courses that belonged to the "engineering" course category to determine what concepts were considered important by engineering programs for first-year engineering students to learn. Keywords extracted from the engineering course descriptions were classified using a revised *First-Year Engineering Course Classification Scheme* recently developed by Reid and his colleagues (Reid, Hertenstein, Fennell, & Reeping, 2013).

Since curricular experiences occur within a program and institutional context (Knight, 2014; Lattuca & Stark, 2009; Pascarella & Terenzini, 2005), curriculum structures should not be examined alone. As Lattuca and Stark (2009) stressed in the book *Shaping the college curriculum: Academic plans in context*, the design of a curriculum is situated within a program and to a larger degree – the institutional context. At the unit-level, matriculation practices – the approaches to be formally admitted to a degree-granting engineering program could have an impact on the arrangement of a first-year engineering curriculum (Chen, Brawner, Orr, & Ohland, 2014). Meanwhile, both the courses offered in the first year and the matriculation model adopted by an engineering program are highly dependent on the characteristics of an institution, such as institutional mission and the availability of educational resources (Chen, Brawner, Ohland, & Orr, 2013; Lattuca & Stark, 2009). As such, instead of looking at the curriculum structures alone, this research made comparisons of first-year engineering curricula for different matriculation models of the engineering programs. Institutional characteristics were compared by matriculation models as well. Using curriculum information of all ABET EAC-accredited programs and data concerning institutional and program characteristics gathered from ABET website (ABET, 2013b) and the Integrated Postsecondary Education Data System (IPEDS) database (U.S. Department of Education, 2012), this study attempted to answer the following research questions:

1. How are the current first-year engineering curricula comprised by the following five categories of courses at institutions with ABET EAC-accredited programs?
    - Engineering
    - Mathematics
    - Science
    - Computer science
    - General education or free electives
2. What are the characteristics of a first-year engineering course regarding the following aspects:
    - The course is mandatory, elective (chosen from a number of courses, required), or optional (recommended but not required) for first-year engineering students

- The course is designed for engineering students in general or for students in specific engineering subfield(s)
- The term in which the course is expected to be taken

3. What subjects are considered by engineering programs to be the foundational knowledge in first-year engineering courses?
4. How do first-year engineering curricula and institutional characteristics differ by matriculation models?

1.3 Significance of the Research

The Engineering Education Research Colloquies (2006) proposed five research areas to underpin the emerging discipline of engineering education. An investigation on first-year curricula, matriculation models, and institutional context addresses key issues related to the research area "engineering learning systems" (p. 259). Setting the work in the context of curricular practices nationwide, this study addressed the fundamental question by providing a broad review of engineering students' early curricular experiences at both program- and institution-level. The course pattern analyzed was related to the pathway students navigated through the admission process to be formally recognized as an engineering student in the institutional context. As CAEE suggested, a broad understanding of the institutional environment is essential to informing and advancing the evolution of engineering education (Atman, et al., 2010). Therefore, results of this study will be highly valuable to the engineering education community.

In addition to addressing fundamental questions of engineering education research, this study has the potential to help program administrators, instructors, and college-bound students to make effective decisions. For administrators and instructors reviewing and revising the curriculum, their work is enhanced when they are familiar with research findings on current national practices (Lattuca & Stark, 2009). Specifically, the composition of first-year engineering curricula can be used by university and engineering program administrators in curriculum development, such as examining the validity of the structure of a first-year curriculum and redesigning the curriculum to better suit the educational goals of the college and the institution. The administrator may find evidence supporting desired changes, such as generating ideas to design a new course or adopting a new matriculation model. Particularly, an overview of topics that are included in first-year introductory engineering courses can be used to assess the effectiveness of individual engineering programs in preparing students to attain ABET outcomes through course content selection. Meanwhile, the relationships among first-year engineering curricula, matriculation models, and institutional characteristics disclosed in this study provide university and engineering program administrators with data helpful in making decisions regarding internal resource allocations. As Gansemer-Topf and Schuh (2003) suggested, the ability to enhance student retention and graduation via strategic allocations of institutional resources could be valuable to institutional planners and leaders. While making course plans, instructors may reflect on what concepts should be included in a first-year engineering course to help students navigate through the pathways of a certain type of matriculation model. Last but not least, an analysis of curricular factors and educational environment that affect engineering student educational experiences at both program- and institution-level provides useful information for college-bound students who intend to major in engineering. Potential engineering students could have a better understanding of what course plans are provided in the first year, what matriculation policies are available, and how their educational experiences may be affected by various institutional factors. Potential engineering students can refer to the information provided in this study to choose the first-year curriculum and matriculation model that best serve their interests.

Both the data gathered in this study and the research findings of this study will be transmitted to and widely disseminated through American Society for Engineering Education (ASEE). The information could potentially serve as a valuable reference for engineering educators and program administrators in both research and practice.

1.4 Definition of Terms

A number of terms were used extensively throughout this study. They are defined below:

- *ABET EAC-Accredited Engineering Program* Post-secondary degree-granting engineering programs that are accredited by the ABET Engineering Accreditation Commission (EAC). An engineering program achieves ABET EAC accreditation by satisfying the accreditation criteria (ABET, 2013a) and complying with ABET policies and procedures.
- *Matriculation Model of an Engineering Program* The matriculation process for first-time college students to be admitted into the college of engineering and subsequently (or simultaneously) be admitted into a specific engineering degree program (Orr et al., 2012).

- *Institutional Control* The principal source of governance of an institution (Astin, 1993). For the purpose of this study, institutional control was referred to whether an institution was public or privately controlled.
- *Carnegie Classification* A taxonomy developed by the Carnegie Foundation for the Advancement of Teaching to differentiate types of institutions including all degree-granting and accredited colleges and universities in the U.S. (Lattuca & Stark, 2009). This study used the 2010 edition of the Basic Carnegie Classification, which included Doctorate-granting Universities, Master's Colleges and Universities, Baccalaureate Colleges, Associate's Colleges, Special Focus Institutions, and Tribal Colleges (Carnegie Foundation for the Advancement of Teaching, 2010).
- *Institutional Mission* "A statement about an institution's identity or vision of itself, articulated to provide its members with a sense of institutional goals and shared purpose" (Lattuca & Stark, 2009, p. 69). For the purpose of this study, institutional mission was referred to a relative emphasis of an institution on instruction, research, and public service, as reflected by the percentage of instruction, research, and public service in total expenditure of an institution (Astin, 1993, p. 330; Lattuca & Stark, 2009).
- *Suggested Course Sequence* A recommended course sequence provided by a degree program to assist students in planning their course schedules. The primary intention of providing a suggested course sequence is to keep students on track to timely degree attainment. In general, a suggested course sequence is a four-year, term-by-term plan for a degree program that shows courses in a proper sequence so that pre- and co-requisite courses are completed first. A course sequence contains information about

mandatory, elective, and optional courses of a degree program, including course title, course credit, and the term in which a course is required, recommended, or offered. Alternative names of suggested course sequence used by degree programs include: four-year curriculum guide, academic planning worksheet, recommended course schedule, and sample four-year schedule.

1.5 Organization

This dissertation was organized into six chapters. This first chapter introduced the background, described the research purpose, presented the research questions, and defined key concepts used in this study. The second chapter introduces the theoretical framework that guided this study. The third chapter provides a review of the literature which furnished the background to this study. The fourth chapter outlines the data collected, variables selected, and how data were analyzed. The fifth chapter presents the findings of this study with discussion. The final chapter summarizes the results, discusses the implications and limitations of this study, and provides recommendations for future research.

CHAPTER 2. THEORETICAL FRAMEWORK

The theoretical framework that guided this study was the Model of Academic Plans in Context developed by Lattuca and Stark (2009). It highlights the influences of institution-level and unit-level factors on undergraduate curriculum, and demonstrates the connections among undergraduate curriculum, curricular influences, and student outcomes. Guided by the Model of Academic Plans in Context, this study investigated the curriculum structures, and examined the relationships among first-year engineering curriculum, matriculation practices of engineering programs, and institutional context that could be highly related to engineering student educational experiences.

The model of Academic Plans in Context defines the undergraduate curriculum as an academic plan that is related to eight elements (as shown in Figure 2.1): "purposes (knowledge, skills, and attitudes to be learned); content (subject matter selected to convey specific knowledge, skills, and attitudes); sequence (an arrangement of the subject matter and experiences intended to lead to specific outcomes for learners); learners; instructional processes (instructional activities); instructional resources (materials and settings to be used); evaluation; adjustment (enhancements to the plan based on experience and evaluation)" (Lattuca & Stark, 2009, pp. 4-5). There are two types of influences that affect the creation and implementation of the curriculum: influences external to the institution and influences internal to the institution. Government, accrediting agencies, and disciplinary associations are examples of external influences. Internal influences are two-fold: institution-level and unit-level. Institution-level influences include institutional resources and governance. Examples of unit-level influences include program goals, faculty beliefs, and student characteristics. As shown in Figure 2.1, external and internal influences, institution-level and unit-level influences interact with each other to create the educational environment, suggesting that administrators and course designers should consider the curriculum design within and among various levels of influences. In addition, the model demonstrates the connection among undergraduate curriculum, curricular influences, and student outcomes. The undergraduate curriculum could have an impact on student development through the educational process, whereas the assessment of student outcomes provides evidence for changes in the curriculum plan and educational environment.

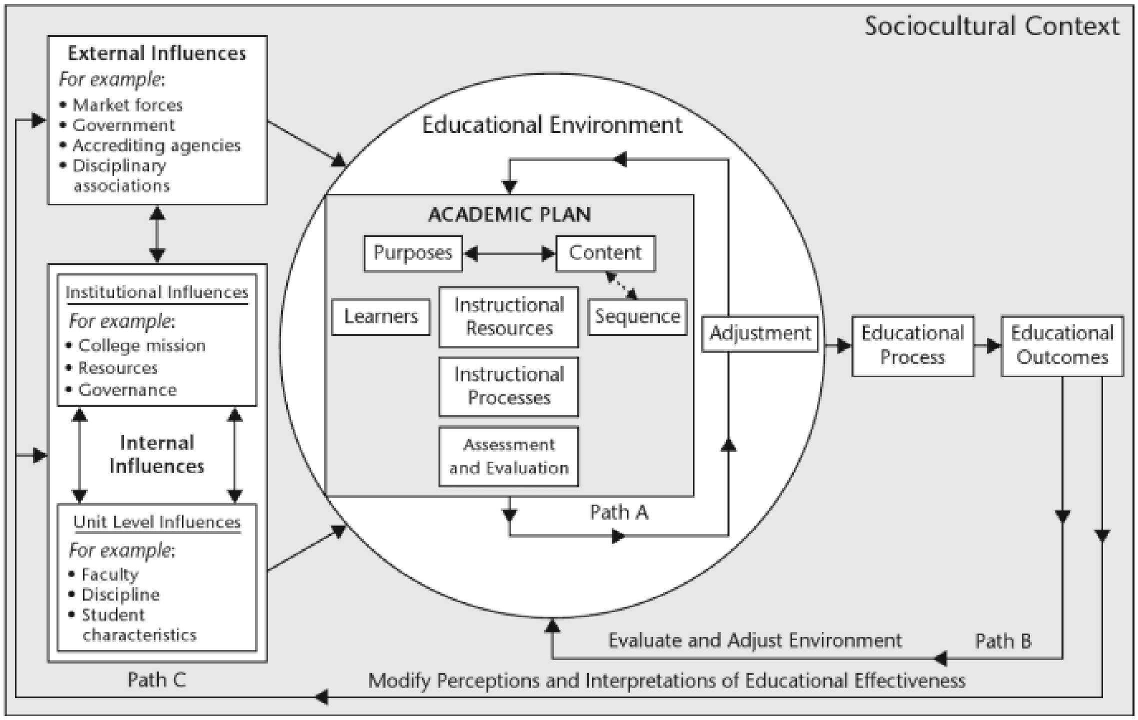

Figure 2.1 Lattuca and Stark's Model of Academic Plans in Context

Note. From *Shaping the College Curriculum: Academic Plans in Context* (p. 5), by L. R. Lattuca and J. S. Stark, 2009, San Francisco, CA: Jossey-Bass. Copyright 2009 by John Wiley & Sons, Inc. Reprinted with permission.

With regard to this study, the model clearly describes that institutional characteristics such as mission and structures, as institution-level influences, could have significant impact on the development of an undergraduate curriculum. The matriculation model of an engineering program, as a unit-level influence, could shape the curriculum plan as well. Accordingly, first-year engineering curricula arrangement and course contents are internally influenced by matriculation models at unit-level and by institutional contexts at institution-level. Meanwhile, the interaction between institution-level influences and unit-level influences suggests that institutions with different engineering matriculation models may have distinct characteristics. As an empirical examination of Lattuca and Stark's model, this research investigated the relationships among first-year engineering curricula, matriculation models, and institutional characteristics. Findings of this study would demonstrate if the compositions of first-year engineering curricula, content selection of engineering courses, and institutional context varied greatly by different matriculation practices of engineering programs.

CHAPTER 3. LITERATURE REVIEW

In this chapter, a review of the literature is conducted to describe previous attempts to investigate the composition of the engineering curriculum, especially the first-year engineering curriculum. Also, efforts to improve students' first-year experiences through the design of introductory engineering courses are examined. In addition, a review of matriculation models, institutional characteristics, and how they are related to student outcomes is performed. Finally, the literature concerning the relationships among undergraduate curriculum, matriculation model, and institutional characteristics is reviewed.

3.1 The Engineering Curriculum and the First-Year Engineering Curriculum

Prior research has investigated the structure and composition of the engineering curriculum from different perspectives. Some studies focused on the entire engineering curriculum. Other studies shed light on the curriculum of a specific engineering discipline or focused on the engineering curriculum in the first-year. Special attention has been paid to the introduction, evaluation, and impacts of introductory engineering courses.

3.1.1 The Overall Engineering Curriculum

A number of studies have focused on the courses and structure of the entire engineering curriculum. For example, in a longitudinal study of student pathway, Adelman (1998) examined the academic records of potential engineering students who had completed at least three engineering-related courses during the first four terms. The three threshold courses included a mathematics course (at least pre-calculus), an engineering design course, and an engineering graphics course. One of the latter two threshold courses could be substituted by an introductory course to an engineering subfield, such as introduction to mechanical engineering. To describe the core curriculum taken by engineering degree recipients, Adelman first categorized all the courses that appeared in those students' college transcripts using a taxonomy he developed (Adelman, 1995). Then he generalized 21 core course categories from over 1,000 course categories. The 21 course categories, called the "empirical core curriculum" (Adelman, 1998, p. 29), accounted for about 60% of total credit hours earned by engineering degree recipients. By comparing changes in the "empirical core curriculum" between the 1972-1984 cohort and the 1982-1993 cohort, Adelman found that calculus took up more time than any other course for both cohorts. On average, 1972-1984 cohort spent 8.7% of total undergraduate time on Calculus, and the percentage for 1982-1993 cohort was 7.1% (Adelman, 1998). Based on student transcripts, Adelman noticed that only four courses outside the Science, Technology, Engineering, and Mathematics (STEM) fields appeared frequently on the engineering degree earners' transcripts. They were introduction to economics, English composition and technical writing, general psychology, and introduction to management (Adelman, 1998). Adelman's longitudinal study evidenced the curriculum practices of potential engineering students. It also reflected changes in students' course taking patterns. While college transcripts recorded the critical courses for engineering degree completers, they could not tell us what courses were expected by the engineering programs for students to take to earn an engineering degree.

To assess the impact of the newly implemented ABET evaluation criteria EC2000, Lattuca and her colleagues (2006) collected survey data from faculty members, program chairs, deans, engineering graduates, and employers. Based on feedback from nearly 1,400 faculty members and program chairs, the research team (2006) concluded that engineering curricula had increased emphasis on professional skills and knowledge associated with ABET outcomes including "communication, teamwork, use of modern engineering tools, technical writing, lifelong learning, and engineering design" (p. 3). Foundational knowledge in mathematics, science, and engineering science was still emphasized. Using a cross-sectional design, Lattuca et al.'s study evidenced that the engineering curriculum had changed significantly to accommodate the EC2000 criteria. A follow-up study that examines the engineering curriculum plans and course contents nationwide could testify if the written requirements and recommendations of engineering programs emphasize the same professional skills and knowledge as listed in Lattuca et al.'s study.

Using qualitative approaches and focusing on the structure of the engineering curriculum, Sheppard et al. (2009) examined the traditional curriculum model based on documents, interviews, and classroom observations of eleven mechanical and electrical engineering programs at six engineering schools. With an aim to determine if the engineering curriculum fitted the real needs of engineering profession, they found that the traditional curriculum was insufficient in preparing students to solve open-ended questions. They concluded that the undergraduate engineering curricula were quite similar to each other nationally. The researchers generalized that the curriculum was made up by four disconnected blocks of courses: (1) mathematics, science, and fundamental engineering science; (2) lab courses; (3) design courses; and (4) ethics. They claimed that the curriculum began with traditional mathematics and science courses. In the sophomore year, mathematics and science courses continued, and engineering fundamental courses as well as disciplinary engineering courses were introduced. Sheppard et al. (2009) noted that theory was taught before practice because engineering project design and lab courses with open-ended problems were introduced late in the curriculum. They also pointed out that humanities and social science courses including engineering ethics were not treated as an integral part of the curriculum. Sheppard and her colleagues' study provided an insightful examination of current engineering curricula. Nevertheless, a larger scale examination of the composition of engineering curricula is needed to complement their qualitative study and make their findings more generalizable.

3.1.2 The Curriculum of an Engineering Discipline

Instead of focusing on the engineering curriculum generally, some researchers shed light on the curriculum of a specific engineering discipline. Russell and Stouffer (2005) conducted a survey of 90 ABET-accredited civil engineering programs to examine the composition of the four-year curriculum of civil engineering. They categorized the courses into three groups according to the course classification used by ABET. Each of the three groups – mathematics and science, engineering topics, and general education was further divided into several sub-groups based on course topics. Courses that could not be categorized into any of the three groups were put into a category called “other”. Russell and Stouffer measured the percentage of each group or sub-group in an average four-year curriculum by credit hours. They found that mathematics and science, engineering topics, and general education accounted for 27%, 51%, and 21% of the total credit hours respectively. The proportionate coverage of topics and courses constituting each group was shown in a similar way. The researchers found that the most commonly required mathematics courses were calculus, statistics, and probability. Specifically, calculus accounted for approximately 8.3% of the total credit hours in a four-year curriculum. This number was consistent with what Adelman revealed from transcripts of potential engineering students that calculus took up 8.7% of total undergraduate time for the 1972-1984 cohort and 7.1% of time for the 1982-1993 cohort (Adelman, 1998). For engineering topics that accounted for over two years of an average four-year curriculum, Russell et al. divided them into seven sub-groups: engineering science fundamentals, civil engineering fundamentals, civil engineering specialties, design courses, technical electives, professional skills, and cooperative education. Russell et al. stressed that the order of the sub-groups represented the general course sequence taken by civil engineering students. Their findings coincided with the results of Sheppard et al.’s (2009) qualitative study that engineering fundamentals were introduced much earlier than design courses. The authors noted the total number of credit hours for general education varied widely among civil engineering programs (between 18 and 58 credit hours), with over half of the general education courses offered in the form of elective courses. Accordingly, they concluded that the undergraduate civil engineering curriculum was highly specialized regarding technical subjects but lacking in focus on liberal arts and the development of professional skills and systems thinking. Russell and Stouffer's study (2005) exemplifies the approaches of using survey data of engineering curricula nationally to analyze the course composition of an engineering subfield. Although their study is positioned at the course title level, the information provided is valuable for curriculum reform and future research.

Jarosz and Busch-Vishniac (2006) extensively examined the syllabi of required technical courses of nine ABET EAC-accredited mechanical engineering programs. Their research purpose was to determine the body of knowledge that defined mechanical engineering. By extracting separate topics and subtopics from the syllabi, Jarosz and Busch-Vishniac derived a frequency list of the topics that were required by at least one-third of the institutions in the sample. They further mapped the topics to the eleven ABET EC2000 Criterion 3 outcomes to determine the degree to which these engineering programs fulfilled the EC2000 criteria. Their findings revealed that most topics mapped onto the first ABET competency "an ability to apply knowledge of mathematics, science, and engineering" (ABET, 2013a, p. 3). In contrast, almost no topic emphasized teams, communication, impact, and contemporary issues. A thorough examination of course contents in their study provided rich information on the characteristics of an individual mechanical program. It allowed the researchers to discover curriculum differences between engineering programs that might not be found by simply checking course titles. An extension of their research to study engineering curricula on a large scale could be challenging with respect to data collection of course syllabi and the identification of various usages of terminologies in the syllabi. Due to differences in research approaches, the descriptions of undergraduate engineering curricula were more comprehensive in Russell and Stouffer's (2005) and Jarosz and Busch-Vishniac's (2006) studies than the four-component curriculum model proposed by Sheppard et al. (2009). Overall, findings of the above three studies are consistent in that the current engineering curriculum emphasizes technical courses strongly, indicating there is room for improvement on the teaching of engineering professionalism and practical skills, and on the integration of knowledge from different domains in the engineering curriculum.

3.1.3 The First-Year Engineering Curriculum and Engineering Courses

A few studies focused specifically on the engineering curriculum in the first year. Brannan and Wankat (2005) conducted two independent surveys to assess the first-year curricula of First-Year Engineering (FYE) programs. The Freshman Programs Division (FPD) survey examined first-year courses that were offered by engineering departments. Based on course descriptions and titles collected from FPD, the researchers extracted ten groups of courses or topics taught by FYE programs. Results showed that 52% of the engineering schools offered an introductory course to the engineering profession. Topics that were usually integrated with other topics included computer tools, programming, design, and graphics. The other survey sponsored by the Center for the Advancement of Scholarship on Engineering Education (CASEE) was interested in courses offered both inside and outside the FYE programs. CASEE provided a list of possible first-year courses for respondents to choose from and asked them to provide information about credit hours for each course and the term in which the course was offered. The survey revealed the distribution of mathematics and science courses as well as general education courses. Results showed that over 50% of the engineering schools required calculus I, calculus II, physics I and physics I lab, chemistry I and chemistry I lab, introduction to engineering I, and English I, the majority of which were more likely to be required in the first semester except physics I with lab. Based on the survey data collected, Brannan and Wankat concluded that the first-year curricula of FYE programs were quite standardized. Although their study was designed for engineering schools that adopted FYE as the matriculation model, survey results provided rich information on the distributions of courses that students took in the first year in FYE programs. Further investigation is needed to explore the first-year curricula of engineering schools that adopt other types of matriculation models to determine if the curricula share similar patterns with the curricula of FYE programs.

Rather than focusing on the whole first-year curriculum that included mathematics and science courses, some studies were interested in the type of courses that introduced students to engineering and its subfields. Landis (1992) conducted a survey in the early 1990s to assess the offering status of an "Introduction to engineering" course in an attempt to develop a model curriculum for an engineering orientation course. Over 67% (168/250) of the engineering programs that were surveyed offered an "Introduction to engineering" course in the first year. Landis further examined the content of the "Introduction to engineering" courses. He found that one third of the introductory courses focused primarily on engineering graphics and computing. Topics that helped first-year students adjust to the new environment and culture of engineering study, such as academic survival skills, were not covered.

Instead of emphasizing the distribution of courses in the first-year engineering curriculum, some researchers attempted to classify introductory engineering courses based on various standards. Bowman et al. (2003) argued that introductory engineering courses could be categorized into four types based on the course format and focus. The first type was general engineering courses that introduced basic engineering principles and skills, including problem solving, communication, computer and programming, and mathematical modeling. General engineering courses were designed for students from all engineering majors. The second type was design-based courses that introduced the design process, teamwork, and problem solving skills. The third type was orientation-type courses that were designed to help students transit smoothly from high school to college. Orientation-type courses included topics such as institutional resources, time management skills, various engineering disciplines and careers, and ethics. The last type was seminar courses that were designed to foster peer interaction and student-faculty interaction in the form of small-group discussions on engineering related topics. In a recent study, Reid et al. (2013) developed a scheme to classify first-year introductory engineering courses. The research group first examined 28 syllabi for first-year introductory engineering courses to identify concepts that appeared frequently in the syllabi. One of the criteria for inclusion in this study was that the course was a common engineering course as opposed to a disciplinary engineering course. For instance, a course titled "Introduction to Engineering" satisfied the requirement, while a course titled "Introduction to Electrical Engineering" did not. An initial framework was formed through syllabi analysis to guide the following workshops and online surveys. Reid et al. (2013) finally derived a classification scheme for first-year introductory engineering courses that included eight main topics: academic advising, communication, design, engineering specific tech/tools, engineering profession, global interest, latent curriculum/professional skills, math skills and applications. Under each main topics, there were topics, sub-topics, and specific topics. For example, if an introductory engineering course includes a lab report, it satisfies the outcome *Communication →Written →Reports →Lab*. *Communication* is the main topic, *Written* is the topic, *Reports* is the sub-topic, and *Lab* is the specific topic. Reid et al.'s work provides a detailed classification system for course designers and instructors to classify introductory engineering courses systematically. Further research with large scale course data could testify the applicability and completeness of the scheme and assess the prevalence of the various topics in U.S. engineering curricula.

Significant research efforts have been put to introduce or evaluate individual first-year courses offered within the college of engineering (Courter, Millar, & Lyons, 1998; Hatton, Wankat, & LeBold, 1998; Hoit & Ohland, 1998; Mourtos & Furman, 2002; Watson, et al., 2010). A common goal of educational practices behind those studies was to create a positive impact on students' desire to persist in engineering through the delivery of an introductory engineering course. For example, Porter and Fuller (1997) studied the impact of a new engineering course on student attitudes about engineering. The course was designed to give students "a taste of engineering thought processes and problem solving methods" (Porter & Fuller, 1997). Students who took the course reported a higher satisfaction with the engineering curriculum and were less likely to consider the first-year courses as "weed out" courses. In a follow-up study, Ohland, Rajala, and

Anderson (2001) confirmed the positive effect of this experimental course on student success. Using a longitudinal database that contained student transcripts, Ohland et al. (2001) found that the retention rate was significantly improved during a four-year period after students took the newly design course. Fortenberry, Sullivan, Jordan, and Knight (2007) studied the effect of a First-Year Engineering Projects course on engineering retention. The course topics included collaborative and team-based learning, experiential projects, open-ended design, and supportive instruction. Students worked on a group project that involved experimental testing. Fortenberry et al. found that the retention rates for students who took the course were uniformly higher in the third, fifth, and seventh semester compared with the rates of those who did not take the course. Using interviews, surveys, and focus groups, Watson et al. (2010) assessed the learning experiences of students in two introduction to engineering courses. Emergent themes of the collected data underpinned the importance of offering engineering courses early in the engineering curriculum to help students develop positive attitudes toward engineering. Specifically, the authors stressed that introductory engineering courses could provide students with a broad overview of the engineering profession and help students understand how the foundational coursework correlated to and was integrated into engineering practices. Overall, research findings of these studies demonstrated the positive impact and underpinned the importance of well-designed introductory engineering courses on student development.

Other studies found that the timing of offering a course in the first year could have an impact on student success. Anderson-Rowland (1998) compared the first- and two-year retention rates of engineering students who took an introduction to engineering design course during their first term with those who took the course a term later. She found that two-year retention rate was higher for students who took the course later, while the first-year retention rate showed no statistical difference. Conversely, when the course was in a different format, Anderson-Rowland found that the first-year retention rate was significantly higher for students who took the course in the first term than students who did not. However, since the impact of student academic abilities (such as SAT scores and first-year academic performances) was not controlled in her study, further investigation is needed to determine if the contradictive results were caused by differences in student quality or changes in the course format. Ohland et al. (2004) examined how retention rates were affected by changing the course requirement of a "gateway" mathematics course. They found that first- and two-year retention rates for students who failed calculus I increased after calculus I was moved from a pre-requisite to a co-requisite course of an introductory engineering course. Accordingly, the researchers suggested that the design of first-year course sequence was extremely important for student success. They also pointed out the importance of introducing students to the engineering discipline early in the first term when they were taking foundational mathematics and science courses, because the introductory engineering course could provide additional context for the calculus course and increase students' interest in engineering.

Prior studies provide important clues about the distribution and categorization of courses in the first-year engineering curriculum. Special attention has been paid to the study of introductory engineering courses. Research approaches that were used to categorize courses and analyze course topics exemplify powerful tools for future investigation of curriculum-related issues. Nevertheless, only a few studies have examined the composition of first-year engineering curricula nationally. Within the existing literature, a nationwide examination of first-year curricula across engineering programs with different matriculation models could not be found. Meanwhile, we still have an inadequate understanding of the core contents of introductory engineering courses that are offered to first-year engineering students and the term in which those courses are recommended or required. Little is known about the requirements of an introductory engineering course, such as whether it is mandatory or optional, or whether it is designed for engineering students in general or for students in specific engineering subfields. This study addressed past limitations in the research by providing a detailed description of the current composition of first-year engineering curricula of all ABET EAC-accredited programs. Particularly, this study analyzed the course descriptions of first-year engineering courses, and examined the requirements of those courses. An understanding of the above issues addresses the core concern of engineering education research. Findings of this study will provide a database for engineering schools to compare their existing first-year curricula with the general practices in other engineering schools revealed in this study.

3.2 Matriculation Model of an Engineering Program

In this section, this study reviews three types of matriculation model: *Discipline*-admitted, *College*-admitted, and *University*-admitted. Further, this study introduces a taxonomy that was developed based on the matriculation model of an engineering program and introductory engineering courses. Studies of the relationships of matriculation models to introductory engineering courses and engineering student outcomes are also reviewed.

3.2.1 Three Types of Matriculation Model

While the national engineering education system has diversified practices, first-time undergraduate students intending to pursue engineering are generally admitted to one of the following three places upon enrollment: *Discipline* (either a specific engineering program or a disciplinary engineering department), *College* (college/school/department of engineering or anywhere else that includes engineering program), and *University* (or a college/school/department/program that does not include any engineering program).

The first type of matriculation model is *Discipline*-admitted. Qualified first-time students intending to pursue engineering enter an institution with *Discipline* as the matriculation practice are free to declare an engineering major when they enter the institution. The majority of students do so and are accepted directly by a specific engineering degree program or a disciplinary engineering department of their choice (Chen, et al., 2013; Orr, et al., 2012). Engineering schools of this type generally allow students who are uncertain about which engineering subfield to pursue to be enrolled as undecided students for a certain period of time. A *Discipline*-admitted program may also provide an alternative path to enroll students who have not completely satisfied initial admission requirements. Those students are conditionally admitted to a special program that is sometimes called Pre-Engineering or Pre-Major. An example of *Discipline*-admitted institution would be the University of Colorado at Boulder. Students satisfied the initial requirements are admitted directly to a specific engineering degree program in the College of Engineering and Applied Science at the institution. Notably, the college has also adopted a program called “GoldShirt” for high school graduates who are not academically prepared for the undergraduate engineering curriculum (Budryk, 2013). Compared with students in the traditional engineering programs, students enrolled in “GoldShirt” spend an extra year to catch up on mathematics, science, and humanities courses before proceeding to the typical first-year engineering courses. While “GoldShirt” provides extra opportunities for students who want to pursue an engineering degree, this study restricted research focus on the primary matriculation approach adopted by an institution to admit qualified first-time students. As a result, University of Colorado at Boulder was treated as a *Discipline*-admitted institution. “GoldShirt” and similar programs were treated as alternative paths of *Discipline* admission.

The second type of matriculation model is *College*-admitted. First-time students admitted to the college/school/department of engineering are identified as engineering students at matriculation, but they are not permitted to specialize for some period of time (Chen, et al., 2013; Chen, et al., 2014). In general, *College*-admitted engineering programs require a core curriculum and central advising for all students before major selection. Upon completion of the lower-division course requirements satisfactorily, students will be considered for admission to a specific engineering degree program. Since the period during which students are “held” by the college generally lasts one year, engineering programs with *College* admission as matriculation practice are usually called First-Year Engineering (FYE) and sometimes called Pre-Professional Engineering. Some *College*-admitted institutions believe this matriculation model provides students with the information necessary to make an informed decision regarding an engineering major while they are taking courses that are common to all engineering majors (Purdue University, 2014b). The FYE program at Purdue University at West Lafayette is an example of the *College* admission matriculation practice. First-year engineering students at Purdue must complete nine courses in the FYE program with a certain level of GPA and make a formal request to be admitted into a specific engineering program (Purdue University, 2014a). It should be noted that First-Year Engineering programs discussed in this research are different from the First-Year Experience programs that aim at integrating first-year students into the university community (Jamelske, 2009). The targeted student bodies differ between the two types of programs. First-Year Engineering programs focus specifically on engineering students, while First-Year Experience programs serve the whole first-year student body at an institution.

The last type of matriculation model is *University*-admitted. Incoming students who want to pursue engineering are formally admitted by the university, or a college/school/department/program that does not include any engineering program. In other words, students intending to major in engineering are not recognized as engineering students at the beginning of their college life. In general, *University*-admitted institutions "hold" all incoming students in the same place regardless of their intended major choices. All first-time students are advised centrally by the university. Similar to students at *College*-admitted institutions, prospective engineering students at *University*-admitted institutions must complete a series of courses (may or may not include engineering course) before entering an engineering degree program. *University*-admitted engineering programs were referred to as Post-General Education (PGE) programs in a recent research study (Orr, et al., 2012). California Institute of Technology is an example of *University*-admitted institution. All first-year students are admitted by the university upon enrollment and are assigned advisers to provide information about the curriculum and institutional policies (California Institute of Technology, 2013). Students notify the Registrar's Office of their selection of major by the middle of the third term and are assigned a related adviser. A special matriculation practice is adopted by the computer engineering program at the University of Houston at Clear Lake. As is stated in the student handbook, students applying for admission to computer engineering are expected to have completed at least 30 credit hours satisfactorily at another community college (University of Houston Clear Lake, 2013). The 30 hours consist of mathematics, basic science, and computer programming courses that are generally required by a first-year computer engineering curriculum. Since this special model is similar to *University*-admitted model except that students complete the required course outside the institution before entering an engineering program, it is categorized as *University*-admitted model in this study.

3.2.2 The Relationship of Matriculation Model to Introductory Engineering Course and Student Outcome

Recently, a research group has been working closely to establish a taxonomy to classify all U.S. undergraduate engineering programs (Chen, et al., 2013; Chen, et al., 2014). The researchers identified significant features of the process of entering engineering programs through semi-structured interviews with College of Engineering representatives at eleven institutions. Also, they collected data from the complete set of

ABET EAC-accredited programs from institutional websites and, in some cases, clarifying phone calls. Finally, they developed a three-dimension taxonomy to categorize all U.S. undergraduate institutions with ABET EAC-accredited engineering programs (Chen, et al., 2014). The taxonomy considers three factors: (1) the matriculation model adopted by the institution; (2) the term in which the first engineering course is required for some or all accredited engineering programs at the institution; and (3) the term in which the first disciplinary engineering course is required for some or all accredited engineering programs at the institution. This taxonomy is described in detail below because it is foundational to this work.

The first dimension of the taxonomy records the place in which first-time students intending to pursue engineering are formally admitted upon enrollment. *Discipline*-admitted, *College*-admitted, and *University*-admitted are recorded as D, C, and U respectively. The second dimension records the term when the first engineering course is required, and if all engineering programs require the first engineering course simultaneously. If the first engineering course is required by all engineering programs, the term when that course is required is denoted using a number starting from 1. For example, if the first engineering course is required in the third term by all engineering programs at an institution, the second dimension of the taxonomy is filled with 3. Otherwise, if the first engineering course is required by some, but not all, engineering programs, the earliest term when the first engineering course is required is denoted using a letter starting from A. For instance, if the first engineering course is required by some programs in the third term, the second dimension of the taxonomy is filled with C. The third dimension records the term when the first disciplinary engineering course is required, and if all engineering programs require it simultaneously. Similar to the notation of the second dimension, the term when the first disciplinary engineering course is required is denoted using a number if the course is required by all accredited engineering programs, and is denoted using a letter if the course is required by some, but not all, programs. For institutions where only one engineering program is accredited by ABET EAC, the second dimension of those institutions is always filled with a number, and the third dimension is filled with the letter X. Table 3.1 summarizes the notations of the taxonomy. Three examples are provided below to show how the taxonomy works:

1. Georgia Institute of Technology is classified as DAA – Students are admitted to a specific engineering program upon enrollment (the first dimension is filled with D). Some majors require a disciplinary engineering course in the first term, but others do not require any engineering course in the first term (the second and third dimensions are filled with A).
2. Purdue University at West Lafayette is classified as C13 – Students are admitted to the First-Year Engineering program in the college of engineering, but not to an engineering discipline (the first dimension is filled with C). All students are required to take a general engineering course in the first term (the second dimension is filled with 1) and are required to take the first discipline-specific course in the third term (the third dimension is filled with 3).
3. Hope College is classified as U1X – Students are admitted at the University level. Students can declare engineering as a major any time after the first term, but usually do so by the end of the second academic year (the first dimension is filled with U). There is only one ABET EAC-accredited program at the university (the third

dimension is filled with X). An engineering course is required in the first term (the second dimension is filled with 1).

Table 3.1 A Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses

Dimension	Label	Definition
First: the place where first-year students intending to pursue engineering are formally admitted upon enrollment	**D**	Discipline. Either a specific engineering program or a disciplinary engineering department
	C	College/School/Department of Engineering (or anything else that includes engineering), first-year/pre-professional engineering program
	U	University, or a college/school/department/program that does not include any engineering program
Second: the term when the first engineering course is required, and if all engineering programs require it simultaneously	**1/2/3… a number**	The term when the first engineering course is required by all engineering programs
	A/B/C… a letter	The earliest term when the first engineering course is required to take by some, but not all, engineering programs. A refers to term 1, B refers to term 2, etc.
Third: the term when the first disciplinary engineering course is required, and if all engineering programs require it simultaneously	**1/2/3… a number**	The term when the first disciplinary engineering course is required by all engineering programs
	A/B/C… a letter	The earliest term when the first disciplinary engineering course is required by some, but not all, engineering programs. A refers to term 1, B refers to term 2, etc.
	X	Only one engineering program is accredited by ABET EAC at the institution

Source: "A Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses," by X. Chen, C. E. Brawner, M. K. Orr, and M. W. Ohland, 2014, Poster session presented at the Annual Conference on The First-Year Experience, San Diego, CA.

Unit-level factors, such as the admission policies of an engineering program, could be more influential to engineering student development than institution-level factors (Ro, Terenzini, & Yin, 2013). Recent studies have examined the impact of matriculation model on engineering student outcomes including choice of major, persistence, the proportion of transfer graduates, total credits earned by graduates, and time-to-graduation (Brawner et al., 2009; Brawner, et al., 2013; Orr, et al., 2012). Comparisons have been made among *Discipline*-, *College*-, and *University*-admitted engineering programs. Using a large-scale longitudinal dataset, Brawner et al. (2009) investigated how the choice of major differed among students in three types of status: (1) designated major in *Discipline*-admitted programs; (2) undesignated students in *Discipline*-admitted programs; and (3) students in First-Year Engineering programs (i.e., *College*-admitted). They found that students in FYE were more likely to choose mechanical engineering but were less likely to choose electrical engineering as their first major than students in *Discipline*-admitted programs. Undecided students in *Discipline*-admitted programs were more likely than designated students in *Discipline*-admitted programs or students in FYE to choose industrial engineering as their first major. The authors hypothesized that variance in major selection might be explained by different first-year experiences in *Discipline*-admitted programs, *Discipline*-admitted programs with undecided status, and in FYE. In spite of the observed differences in major selection practices, in a later qualitative research done by Brawner et al. (2013), students reported that matriculation models had little impact on their choice of an engineering major. The researchers interviewed 61 sophomore students majoring in *Discipline*-admitted programs and in FYE programs to investigate the impact of matriculation model on selection of institution and major. Many students responded that they had decided which engineering major they would like to choose before college. Neither their choice of institution nor their choice of major was affected by the matriculation model adopted by the institution. Yet the researchers discovered that the first-year experience, particularly introductory engineering courses, was associated with a difference in students' choice of major in sophomore year.

Orr et al. (2012) compared the effects of *Discipline*-admitted, FYE, and *University*-admitted at ten public institutions on engineering student persistence, the proportion of transfer students in engineering graduates, total credit hours completed by engineering graduates, and time-to-graduation. They found that students in *Discipline*-admitted programs and in FYE had similar outcomes. For example, first-time college students in *Discipline*-admitted programs and in FYE had similar persistence rates within engineering from the fourth term to the sixth year. Engineering graduates earned the same number of credit hours and enrolled in a similar number of terms to graduate. The percentages of engineering graduates who switched from other majors were quite similar in *Discipline*-admitted programs and in FYE. One notable difference between *Discipline*-admitted programs and FYE was the percentage of graduates who transferred from other institutions. Only 13.6% of engineering graduates in FYE were transfer students, while the percentage more than doubled in *Discipline*-admitted programs (28.5%). Another difference existed in the persistence rate with the first major. Orr et al. found that FYE had higher proportion of graduates (89%) who completed their degree within six years in their first major. The percentage for undesignated and designated students in *Discipline*-admitted programs was 4% lower and 11% lower respectively.

Compared with students in *Discipline*-admitted programs and in FYE, Orr et al. (2012) found that students in *University*-admitted programs had very different outcomes. First-time engineering students in *University*-admitted programs had a much lower persistence rate than students in *Discipline*-admitted programs and in FYE in the fourth term, and the gap grew over time. Only 32% of *University*-admitted students graduated within six years, while the graduation rates for students in *Discipline*-admitted programs and in FYE were 50% and 51% respectively. *University*-admitted graduates completed nearly 13 more credit hours than *Discipline*-admitted and FYE graduates and spent an additional 1.67 terms at institution compared to *Discipline*-admitted and FYE graduates. Nevertheless, *University*-admitted programs were more attractive to transfer students and switchers: 46.5% of engineering graduates in *University*-admitted programs were transfer students. The percentage was much higher than 28.5% in *Discipline*-admitted programs and 13.6% in FYE. On average, 25.5% of engineering graduates in *University*-admitted programs were students who switched from other majors, compared to only 10.7% in *Discipline*-admitted programs and 9.8% in FYE.

Based on the findings, Orr and her colleagues (2012) concluded that each matriculation model had advantages and disadvantages. Both *Discipline*-admitted programs and FYE provided early experiences about engineering so that students recognized themselves as engineering students at matriculation. An early commitment to the field might lead to higher persistence rates and shorter path toward degree attainment. However, these two matriculation models were less successful than *University*-admitted programs in recruiting students who did not enter engineering upon enrollment. While FYE was the most efficient in helping students choose their engineering majors, it had the smallest percentages of graduates who were transfer students and switchers. As Orr et al. (2012) stated, "the common courses and experiences that tend to keep students on this path also seem to keep transfers and switchers out" (p. 4). Although *University*-admitted programs had the lowest persistence rates, the *University*-admitted matriculation model provided more flexibility for transfer students and switchers to migrate into engineering. A longer time to graduate in *University*-admitted programs could be a hindrance to degree completion, but it was possible that students in *University*-admitted programs used some of their credits towards a double major or a minor.

In a follow-up study, Orr and her colleagues (2013) investigated the combined effects of a first-year engineering course (or course sequence) and matriculation model on student outcomes. The first-year course or course sequence studied was restricted to general introduction to engineering course that was designed for all first-time engineering students regardless of their choice of major. Students were categorized into two groups: (1) students with designated majors in *Discipline*-admitted programs, and (2) undesignated students (include undesignated students in *Discipline*-admitted programs, conditionally admitted students, and students in FYE). The researchers found that a general introduction to engineering course or course sequence was positively associated with student retention to the eighth term. The retention rate was even higher for designated students in *Discipline*-admitted programs than the rate for undesignated students. Undesignated students were more likely to stay in their first engineering major until their eighth enrolled term than designated students in *Discipline*-admitted programs. The effect was more prominent if a general introduction to engineering course or course sequence was required by the engineering program. As the authors pointed out, results should be interpreted with caution because institutional characteristics such as size, quality, and selectivity may also have an influence on student persistence and other outcomes.

The above studies have demonstrated a variety of ways that matriculation practices and introductory engineering courses could shape the engineering pathway, suggesting that unit-level factors could have great influences on engineering student outcomes. Nevertheless, the relationship between matriculation models and the composition of first-year engineering curricula, and the correlation between matriculation models and institutional characteristics are less studied. An understanding of how these factors are related provides a holistic view that may be useful for identifying engineering program structures most relevant to desired student outcomes.

3.3 Institutional Characteristics

In this section, a review of the literature concerning the effects of conventional institutional characteristics on student outcomes is conducted. In addition, the literature concerning the relationships among institutional characteristics, undergraduate curriculum, and matriculation model is reviewed.

3.3.1 Institutional Characteristics and Student Outcome

A major theme in the literature on college impact involves inquiry into the influences of institutional characteristics on student development (Astin, 1993; Pascarella & Terenzini, 1991, 2005; Tinto, 1993). The educational environment provided by an institution could affect student learning and engagement, which in turn affect student retention, graduation, and other educational outcomes (Astin, 1975, 1999). This study reviews the impacts of the most frequently examined institutional characteristics including: institutional control, type, setting, selectivity, size, student-faculty ratio, average faculty salary, institutional expenditures, residential status of first-year students, and financial aid.

Control

The majority of studies focusing on the effect of institutional control (public versus private) have found that private universities are more likely to have higher retention and graduation rates (Morrison, Griffin, & Marcotullio, 1995; Oseguera, 2005; Ryan, 2004). For example, both Ryan (2004) and Oseguera (2005) found that attending private universities was positively related to four- and six-year graduation rates of first-time full-time degree-seeking students. Titus (2004), however, found no significant difference between retention rates at public and private institutions for first-time full-time degree-seeking students. After a careful look at retention historically, Berger and Lyon (2005) pointed out that private institutions had a higher chance to enroll better prepared students and thus made them more likely to get better results. Scott, Bailey, and Kienzl (2006) concurred that the difference in mean graduation rates of public and private institutions could be explained by the differences in resources and student populations. After controlling for institutional resources as well as student characteristics, Scott et al.'s (2006) regression model showed that six-year graduation rates of public institutions were slightly higher than the graduation rates of private institutions. Focused specifically on minority engineering students, Morrison, Griffin, and Marcotullio (1995) found that the mean graduation rate for minority engineering students at private institutions was significantly higher than their counterparts at public institutions (60.5% versus 38.5%). For nonminority engineering students, the effect of institutional control on degree attainment was non-significant (Morrison, et al., 1995).

<u>Institutional Type</u>

One general measure of institutional type is the *Carnegie Classification of Institutions of Higher Education* (Carnegie Foundation for the Advancement of Teaching, 2014a). The Carnegie Classification is a widely used framework for classifying colleges and universities in the U.S. (Hamrick, Schuh, & Shelley, 2004; Pike, Smart, Kuh, & Hayek, 2006; Schreiner, 2009). Designed to support educational research, the Classification identifies groups of comparable institutions for researchers and institutional personnel to analyze either individual institutions or the system of higher education. First published in 1973, the Carnegie Classification has undergone revisions in 1976, 1987, 1994, 2000, 2005 and 2010 to accommodate changes among colleges and universities. In its former editions until 2000, the Classification used a single monolithic classification scheme (Carnegie Foundation for the Advancement of Teaching, 2014b). To mitigate the effects of using the Classification as a ranking system, the 2005 and 2010 editions adopted a multiple-classification approach to reflect the complexity of institutional characteristics. Hamrick et al. (2004) used the 1994 edition of the Carnegie Classification to group the institutions. The researchers perceived that Research I institutions were the most prestigious and the Bachelor's II institutions being the opposite. They found that institutions at higher Carnegie Classification levels had higher graduation rates. Accordingly, Hamrick et al. (2004) suggested that Carnegie Classification exerted its influence on students through institutional and political processes. Schreiner (2009) found similar results based on the 2005 edition of the Basic Carnegie Classification. She found that first-year students were more likely to persist at institutions with a Classification of Research/High or Very High. Despite that retention and graduation rates were found to be higher at research institutions, Pike et al. (2006) discovered that attending public doctoral-research universities, as compared to baccalaureate institutions, was negatively related to student engagement such as student-faculty contact. Besides Carnegie Classification, the highest degree offered by an institution is also used as measure of institutional type. Volkwein and Szelest (1995) tested the effect of the highest degree offered by an institution (associate's, bachelor's, and graduate degree) on student loan repayment and default behaviors. They found little support for the hypothesis that the highest level of degree an institution offered had an impact on student loan behavior.

Setting

Goenner and Snaith (2003) stated that the setting of an institution (e.g., city, suburb, rural, etc.) provided different environments to students and therefore was relevant to student outcomes. Hamrick et al. (2004) found that a more urbanized location was positively associated with a higher graduation rate at four-year public institutions. Scott and his colleagues (2006) confirmed the positive and significant effect of urbanization on six-year graduation rates at public institutions. The effect was non-significant for private institutions (Scott, et al., 2006).

Selectivity

Among institutional characteristics, selectivity has been found to be a key predictor of retention and graduation (Astin, 1993; Astin & Oseguera, 2005; Morrison, et al., 1995; Schreiner, 2009). For instance, Astin (1993) found that institutional selectivity, as measured by average high school grades and SAT scores of entering cohort, accounted for over half of the variance in retention rates of baccalaureate-granting institutions. Other studies measured selectivity using the percentage of applicants accepted (Hamrick, et al., 2004; Morrison, et al., 1995; Schreiner, 2009). For example, Hamrick et al. (2004) discovered that the admission rate was negatively related to graduation rates at public four-year institutions. Schreiner (2009) found that selectivity was significantly related to retention rates of first-time full-time students at four-year institutions. Focusing on engineering schools, Morrison and her colleagues (1995) found that selectivity was the most significant factor related to degree attainment of engineering students. In their study, selectivity was measured by the percentage of applicants accepted by the institution, students' high school class rank, and standardized test scores of first-year students entering the institution. Morrison et al. (1995) found that the more selective an institution was, the higher graduation rates for both minority and nonminority engineering students. Oseguera (2005) concluded that highly selective institutions not only had more qualified students, but also had more resources available to students, and therefore were more likely to promote student success.

Size

Researchers have demonstrated the contradictive effects of institutional size on student outcomes (Astin, 1993; Oseguera, 2005; Ryan, 2004; Titus, 2004). Titus (2004) examined the effects of institution-level variables on the persistence of first-time full-time degree-seeking undergraduates attending four-year colleges and institutions. Using multilevel modeling, he found that institutional size, measured by total enrollment of first-time full-time degree-seeking undergraduates, was positively related to student persistence after taking student-level variables into account. Similarly, Ryan (2004) claimed that institutional size had a positive effect on six-year graduation rates of first-time full-time degree-seeking undergraduates at four-year institutions. He suggested that higher graduation rates at large institutions might be due to a higher level of social and academic support services. Conversely, studies by Astin (1993) and Oseguera (2005) posited the negative effect of institutional size on student graduation. Astin (1993) discovered that institutional size, either measured by total full-time equivalency (FTE) enrollment or total undergraduate FTE enrollment, had direct negative effects on students' college experience and enrollment in graduate school. In a study of contextual effects for different racial groups, Oseguera (2005) found that institutional size measured by undergraduate enrollment and graduate enrollment had a negative effect on four-year bachelor degree attainment of all ethnic groups at baccalaureate-granting institutions.

Institutional Quality

Student-faculty ratio and average faculty salary are two commonly used measures of institutional quality (Astin, 1993; Goenner & Snaith, 2003; Solmon, 1975; Toutkoushian & Smart, 2001). The assumption is that a lower student-faculty ratio is positively correlated to a higher level of student-faculty interactions (Oseguera, 2005). Higher paid faculty generally have more experiences, teach better, or have more prestige from research (Solmon, 1975). Nevertheless, student-faculty ratio and average faculty salary were found to have only modest or indirect effects on student development (Astin, 1993; Toutkoushian & Smart, 2001). For example, Astin (1993) found that student-faculty ratio had only indirect negative effects on degree completion, while average faculty salary had direct effects on student development such as student satisfaction with faculty. Toutkoushian and Smart (2001) suggested that a higher student-faculty ratio did not lead to reductions in student gains except communication skills. They also failed to find any significant relationship between average faculty salary and student development.

Mission and Student Services Related Expenses

Priorities of allocating financial resources not only reflect an institution's commitment to different functions but also affect student outcomes (Toutkoushian & Smart, 2001). Some expenditures (such as instructional expenditure) are more closely related to student learning than others (such as public service expenditure) (Rock, Centra, & Linn, 1970; Toutkoushian & Smart, 2001). As Astin (1993) highlighted, the percentage of student service expenditure measures the institutional commitment to student support service. Similarly, the percentage of instructional expenditure measures the institutional commitment to the instructional process (Astin, 1993). Numerous studies found that student service expenditure and instructional expenditure had significant but inconsistent relationships with student development (Astin, 1993; Gansemer-Topf & Schuh, 2006; Oseguera, 2005; Ryan, 2004; Smart, Ethington, Riggs, & Thompson, 2002). For example, Astin (1993) suggested that the percentage of total expenditures invested in student services had positive effects on student outcomes such as satisfaction with faculty. The proportion of total expenditures invested to instructionally related activities had similar but more modest effects. Oseguera (2005) concurred that both student service and instructional expenditures were positively related to four-year graduation rates of first-time full-time degree-seeking students. Ryan (2004) acknowledged the positive effect of instructional expenditure on graduation rates, but failed to substantiate the positive relationship between student service expenditure and degree attainment. In a longitudinal study, Smart, Ethington, Riggs, and Thompson (2002) found that student services expenditure had a positive effect on students' leadership competencies, while the effect of instructional expenditures was negative. Also, researchers have conflicting conclusions about the effects of academic support expenditure on student gains (Oseguera, 2005; Ryan, 2004; Toutkoushian & Smart, 2001). Both Ryan (2004) and Oseguera (2005) suggested a positive relationship between academic support expenditure and graduation rates of first-time full-time degree-seeking students. In contrast to what was expected, Toutkoushian and Smart (2001) found that students enrolled at institutions with a higher percentage of expenditures devoted to academic support had lower gains in learning/knowledge and communication skills.

Residential Status

Living on campus, as Astin (1993) suggested, indicates whether an institution is "characterized by a residential climate" (p. 63). The percentage of first-year students living on campus is positively related to degree completion and other educational outcomes (Astin, 1993; Oseguera, 2005; Ryan, 2004). For instance, both Ryan (2004) and Oseguera (2005) found that living on campus enhanced graduation rates. Astin (1993) demonstrated that students perceived a better relationships with the faculty at institutions with a higher percentage of first-year students living on campus. Similarly, Lounsbury and DeNeui (1995) noted that students who lived on campus had a greater sense of community. Living on campus provides students with the opportunity to socially integrate into the campus community, which may increase their commitment to the institution and therefore is related to desirable student outcomes (Tinto, 1975).

Financial Aid

Researchers have found that the total amount of financial aid (scholarships, grants, loans) is positively related to student persistence (Hoyt, 1998; Somers, 1994; St. John, Kirshstein, & Noell, 1991). For instance, Hoyt (1998) compared the retention rates between students who received any type of financial aid to students who did not. He discovered that students receiving financial aid were more likely to persist. Dowd (2004) stressed the likelihood that financial aid enabled students to be more socially integrated, and thus improved students' academic performance and retention. As one of the largest need-based financial aid programs in the U.S., the effects of Pell Grant on student access has been studied thoroughly. Most studies found little to no persuasive evidence that the program affected enrollment decision of incoming students (Hansen, 1983; Kane, 1995; Seftor & Turner, 2002). Among a few studies that examined the relationship between Pell Grant and retention, Bettinger (2004) discovered that Pell Grant significantly reduced dropout rates of first-year students at Ohio's public institutions.

Overall, earlier work indicates that conventional institutional characteristics, such as institutional control and size, have only moderate or indirect effects on student outcomes. As Ro and her colleagues (2013) suggested, "the conventional descriptors are too distal from students' experiences to have much effect on differences in outcomes (p. 253). Nevertheless, institution-level factors shape the kinds of educational experiences students have, which are highly related to student outcomes. Also, a review of the influences of institutional characteristics provides a pool of institution-level variables to be considered in the investigation of the relationships between institution-level factors and unit-level factors.

3.3.2 The Relationship of Institutional Characteristics to the Undergraduate Curriculum and Matriculation Model

"Institutional constraints do indeed play a role in the type of curriculum a college may adopt" (Hurtado, Astin, & Dey, 1991, p. 146). In a recently published book *Shaping the College Curriculum: Academic Plans in Context*, Lattuca and Stark (2009) introduced the model of academic plans in context to demonstrate the influential factors of curriculum development. The authors suggested that institution-level variables could have significant impact on curriculum planning. As Lattuca and Stark (2009) stressed, most academic programs "exist within institutions and are thus supported by organizational infrastructures. Aspects of these infrastructures, particularly college mission, financial resources, and governance arrangements, can have a strong influence on curricula" (p. 13). Specifically, the authors proposed that institutional mission, distinguished by an institution's relative emphasis on research, teaching, and service, was an important influence on curriculum planning. Institutional type differentiated by Carnegie Classification also affected the development of curricular plans because it specified an institution's educational characteristics, such as teaching responsibilities and research emphasis. The authors highlighted that institutional resources and costs had significant influences on curricular decisions by constraining the numbers and types of courses a program offered. Other institutional characteristics mentioned in their book that might affect curricular choices include control and geographic location of an institution. Besides institution-level influences, Lattuca and Stark (2009) stressed that unit-level variables characterizing a college/department/program could also “directly affect the selection and sequencing of content and the choice of instructional processes” (p. 14). Further, they pointed out that “institutional-level influences and unit-level influences are interrelated in the task of curriculum planning” (Lattuca & Stark, 2009, p. 67).

In the development of a taxonomy to classify all U.S. institutions with ABET EAC-accredited programs (as shown in Table 3.1), Chen et al. (2013; 2014) observed correlations between the matriculation model an institution adopted and characteristics of that institution. For example, institutions with only one ABET EAC-accredited program, regardless of the matriculation model they adopted, had lower engineering enrollment and graduation than institutions with multiple accredited programs. Also, institutions with one accredited program were more likely to be private and rural institutions compared to population averages. For institutions with multiple accredited programs, *College*-admitted institutions were more likely to be public, urban, and larger than *University*-admitted institutions (Chen, et al., 2014). The studies of Chen et al. (2013; 2014) provide some hints on how the matriculation model and some of the institutional characteristics are correlated. A more detailed investigation is needed to determine if course content and requirements of the first-year engineering courses vary by matriculation models, and if matriculation models relate to more variables measuring institutional characteristics.

A review of the existing literature suggests that many studies have focused on the engineering curriculum, matriculation model, and institutional characteristics – but separately. Only a few studies explored relationships among these factors. This research added to what had been learned from these prior studies by examining how the first-year engineering curriculum and institutional context varied by matriculation models. Findings of this study will improve our understanding of the intercorrelations among external factors that may have significant influences on engineering student persistence and degree attainment.

CHAPTER 4. METHODS

This chapter outlines the scope of this study, summarizes the data sources and variables selected for this study, describes the statistical technique used, and provides detailed analyses of engineering curricula compositions and engineering course keywords.

4.1 Description of Data

In an attempt to answer the research questions, this study examined the first-year engineering curricula and characteristics of institutions with at least one ABET EAC-accredited bachelor's engineering program. All 408 U.S. institutions with at least one ABET EAC-accredited program were selected for this study, representing a broad spectrum of educational settings. According to the most current data available in the *Digest of Education Statistics* (Snyder & Hoffman, 2013b) on the website of National Center for Education Statistics (NCES), there were 498 degree-granting institutions that conferred bachelor's degrees in engineering fields in 2011-2012 (Snyder & Hoffman, 2013c). Hence, institutions studied in this research represent approximately 82% of the nation's degree-granting institutions that confer bachelor's degrees in engineering. From another perspective, there were 81,006 engineering bachelor's degrees granted between July 2011 and June 2012 at 403 institutions studied in this research (information on the number of engineering bachelor's degrees was unavailable for the remaining five institutions). According to the *Digest of Education Statistics*, the number of engineering bachelor's degrees conferred by postsecondary institutions in 2011-2012 was 81,382 (Snyder & Hoffman, 2013a). Therefore, over 99% of the engineering bachelor's degrees were granted at institutions studied in this research.

One major concern of focusing exclusively on ABET EAC-accredited programs is that the accreditation criteria may decrease the flexibility in curriculum design and therefore the curricula of accredited engineering programs may be similar to each other. However, as Russell and Stouffer (2005) pointed out in their national analysis of engineering curricula of ABET EAC-accredited civil engineering programs, institutions have the flexibility to organize and present their curricula to ABET. A prior study by Chen and her colleagues (2013) demonstrated the existence of variance in requirements of first-year introductory engineering courses offered by accredited engineering programs. Therefore, it makes sense to restrict the research scope to ABET EAC-accredited programs and acknowledge the potential disadvantage of sample selection in this study. An understanding of the curriculum structures of ABET EAC-accredited programs provides a baseline for future research to explore the curricula of engineering programs that are not accredited by ABET.

This study collected data from three sources. The list of institutions with ABET EAC-accredited programs and basic information on the institutions were downloaded from the ABET Website. Primary institution-level data were derived from IPEDS. The suggested first-year course sequences, first-year engineering course descriptions, admission and advising policies of all accredited engineering programs were downloaded from their respective university, college, and departmental websites.

4.1.1 Data from the ABET Website

The most up-to-date list of 408 institutions was downloaded from the ABET website in October 2013 (ABET, 2013b). Based on the information downloaded from www.ABET.org, an initial spreadsheet was created that contained the following fields that were relevant to this study:

1. Institution name
2. ABET EAC-accredited bachelor's program and degree names
3. The number of accredited engineering programs per institution
4. Website (URL for institutional website)
5. Location (city, state, country)

In the calculation of the number of accredited engineering programs per institution, this study followed three rules: (1) if a program was accredited under more than one set of program criteria at an institution, it was counted only once (e.g. electrical and computer engineering offered at Carnegie Mellon University satisfied the criteria for computer engineering and the criteria for electrical and electronics engineering); (2) if a program was accredited twice because it was offered in two different campus locations of the same institution, it was counted only once (e.g. mechanical engineering offered at the University of Maryland-College Park was accredited twice because it was offered in two locations); (3) if a program was no longer available, as shown on the institutional website, it was not counted even if it was listed on the ABET website (e.g. electrical engineering was no longer available in Alfred University, but it was still listed on the ABET website by the time this study collected data). Based on the above three rules, there were 1,976 ABET EAC-accredited programs offered at 408 institutions. Seven programs were counted twice because they were joint programs held by two institutions. Specifically, six joint programs were held by Florida Agricultural and Mechanical University and Florida State University. One joint program was held by North Carolina State University at Raleigh and University of North Carolina at Asheville. Accordingly, the number of non-repeated ABET EAC-accredited programs offered at 408 institutions was 1,969.

4.1.2 Data from IPEDS

In addition to basic institutional information obtained from the ABET website, the primary institution-level data were derived from IPEDS (U.S. Department of Education, 2012) for the 2011-12 academic year (the most recent available at the time of this study). Conducted by NCES, IPEDS is a comprehensive, longitudinal data collection system for postsecondary education. The IPEDS database incorporates nine interrelated survey components and contains over 3,000 variables on enrollments, completions, finances, and other attributes for all U.S. institutions. Due to its ease of availability and high-quality data, IPEDS is widely used in higher education research to explore various institutional characteristics that are related to student development.

From the pool of variables available in IPEDS, this study selected the following 33 variables that were commonly used to describe the basic characteristics of an institution and its engineering programs. Variables were drawn or calculated from six survey files of IPEDS:

1. The file of institutional characteristics: institutional control, Carnegie Basic Classification, highest level of degree offered, degree of urbanization, acceptance and

enrollment rates, availability of on-campus housing, and requirement of first-time full-time degree/certificate-seeking students to live on campus;

2. The file of enrollment: total students enrolled, total undergraduate students enrolled, total first-time full-time degree/certificate-seeking undergraduate students enrolled, total engineering students enrolled, total undergraduate engineering students enrolled, total first-time full-time degree/certificate-seeking undergraduate engineering students enrolled, engineering students as a percentage of total enrollment, undergraduate engineering students as a percentage of total enrollment, first-time full-time degree/certificate-seeking undergraduate engineering students as a percentage of total enrollment, and student-faculty ratio;
3. The file of completion: total number of bachelor's degrees granted, total number of master's degrees granted, total number of doctoral degrees granted, total number of engineering bachelor's degrees granted, and engineering bachelor's degrees as a percentage of total degrees granted;
4. The file of instructional staff/salaries: average salary per month of full-time, non-medical, instructional staff;
5. The file of finance: instructional, research, public service, student service, and academic support expenses each as a percentage of total expenses;
6. The file of student financial aid: average amount of grant aid received by undergraduate students, average amount of grant aid received by first-time full-time degree/certificate-seeking undergraduate students, percentage of undergraduate students receiving Pell Grant, and percentage of first-time full-time degree/certificate-seeking undergraduate students receiving Pell Grant.

Together with the number of ABET EAC-accredited programs per institution calculated from the ABET website, a complete list of 34 variables measuring 10 dimensions of institutional characteristics is provided in Table 4.1. Information describing four institutions (1% of the institutions with ABET EAC-accredited programs) was unavailable in IPEDS, therefore they were eliminated from the study of institutional characteristics. In other words, most of the variables listed in Table 4.1 were available for the analysis of institutional characteristics in 404 out of 408 institutions.

Table 4.1 Variables Measuring Ten Dimensions of Institutional Characteristics

Dimension	**Variable**
Control	Public or private
Type	Carnegie Basic Classifications (2010 version) Highest level of degree offered (bachelor's degree, post-baccalaureate certificate, master's degree, post-master's certificate, doctoral degree)
Setting	Degree of urbanization (city, suburb, town, or rural)
Selectivity	Acceptance rate (number of accepted students divided by number of applicants) Enrollment rate (number of students who actually attended divided by number of accepted students)
Size	Total students enrolled (fall 2012) Total undergraduate students enrolled (fall 2012) Total first-time full-time degree/certificate-seeking undergraduate students enrolled (fall 2012) Total engineering students enrolled (fall 2012) Total undergraduate engineering students enrolled (fall 2012) Total first-time full-time degree/certificate-seeking undergraduate engineering students enrolled (fall 2012) Engineering students as a percentage of total enrollment (fall 2012) Undergraduate engineering students as a percentage of total enrollment (fall 2012) First-time full-time degree/certificate-seeking undergraduate engineering students as a percentage of total enrollment (fall 2012) Total bachelor's degrees granted (granted between July 1, 2011 and June 30, 2012) Total master's degrees granted (granted between July 1, 2011 and June 30, 2012) Total doctoral degrees granted (granted between July 1, 2011 and June 30, 2012) Total engineering bachelor's degrees granted (granted between July 1, 2011 and June 30, 2012) Engineering bachelor's degrees as a percentage of total degrees granted (granted between July 1, 2011 and June 30, 2012) Number of ABET EAC-accredited engineering programs

Table 4.1 continued.

Dimension	Variable
Quality	Average salary per month of full-time, non-medical, instructional staff
	Student-faculty ratio
Mission	Instructional expenses as a percentage of total expenses Research expenses as a percentage of total expenses Public service expenses as a percentage of total expenses
Student services related expenditures	Student service expenses as a percentage of total expenses Academic support expenses as a percentage of total expenses
Residential status	Availability of on-campus housing (dichotomous) First-time full-time degree/certificate-seeking students required to live on campus (dichotomous)
Financial aid	Average amount of grant aid received by undergraduate students (federal, state, local, institutional or other sources of grant aid dollars) Average amount of grant aid received by first-time, full-time degree/certificate-seeking undergraduate students (federal, state, local, institutional or other sources of grant aid dollars) Percentage of undergraduate students receiving Pell Grant Percentage of first-time, full-time degree/certificate-seeking undergraduate students receiving Pell Grant

4.1.3 Data from Institutional Websites

Besides institution-level data, this study obtained program-level data from university, college, and departmental websites. The most recent versions of the suggested first-year course sequences, first-year engineering course descriptions, and admission/advising policies of ABET EAC-accredited programs were gathered from June to December 2013. In most cases the curriculum plans collected were in effect during the 2013-14 academic year, otherwise curriculum plans of previous years were used. For some programs, their first-year curricula or course descriptions were unavailable online. Those programs were eliminated from the study of curricula compositions and the analysis of course keywords respectively. The approach of gathering first-year engineering curricula and admission information online on a large scale has two advantages: (1) it is based on information that is accessible to the public; and (2) it represents the educational experiences of all first-year engineering students across the country.

Suggested First-Year Course Sequence

A suggested course sequence typically contains information about course scheduling and requirements of a degree program, including course title, course credit, the term in which a course is required, recommended, or offered, and notes about extra guidance for choosing a course. A course description typically includes course content, course prerequisites and co-requisites, and sometimes provides information on the department by which the course is offered. As such, the suggested course sequence and course descriptions are excellent sources of data about an engineering program's formalized curriculum (Hurtado, et al., 1991). As an "input-based" approach, a catalog-based study of first-year engineering curricula could not provide information on the quality of the instruction or how well engineering students understand the concepts (Stephan, 1999). Nevertheless, the schedule, requirement, and content of engineering courses specify what an engineering program intends its curriculum to be and what it expects students to do so as to graduate. While some researchers turn to student transcripts as the primary source of curriculum data, this study is able to understand important issues such as the structure of the first-year engineering curriculum and the frequently listed concepts in first-year engineering course descriptions.

In the collection of suggested first-year course sequences, attention was restricted to one suggested course sequence per accredited engineering program to make sure that each program had equal weighting in the calculation. This study followed three rules in choosing a course sequence when multiple course sequences were presented for an engineering program: (1) if both a four-year plan and a five-year plan were provided for an engineering program, only the four-year plan was considered; (2) if both a sequence for students in general and a sequence for honors track students were provided, only the sequence for students in the general path was considered; and (3) if each concentration (or emphasis, option, specialization, track) of an engineering program had its own suggested course sequence, only the suggested course sequence for the general path was consider, otherwise the first concentration in alphabetical order was considered. In most cases, engineering programs only provided four-year plans for students in the general path. While a few engineering programs provided separate plans for their concentrations, they generally required the same course sequence in the first year (i.e. the first-year course sequences were identical across concentrations). Consequently, the bias arose from nonrandom selection of suggested course sequence was limited.

A spreadsheet was created to record the information on first-year courses. Information collected per course included the following fields:

1. Course prefix
2. Course title
3. The term in which the course is offered
4. Course credit
5. Whether the course is mandatory, elective (chosen from a number of courses, required), or optional (recommended but not required)
6. Course category (choose from engineering, mathematics, science, computer science, and general education/free electives)

7. If a course is categorized as an engineering course, further determine if it is designed for engineering students in general or for students in specific engineering subfield(s)
8. Course description
9. Offering department (if available)
10. Engineering program name
11. Institution name

For the 4th field, if a course's credits were given in the form of a range as opposed to a number, this study assigned the average number of the range as its credits. For example, a course with credit hours 3-4 was considered a 3.5 credit hours' course. Similarly, course credits of an elective course was calculated by averaging the course credits of all courses to be chosen from.

For the 6th field, a course was categorized into one of the five groups by its prefix, title, and description. Science courses include biology, chemistry, materials science, and physics courses. Computer science courses include computer science, computer programming, and information science courses offered by the department/school/division of computer science/computer information science/computer information systems. A general education/free electives course is a course that belongs to none of these categories: engineering, mathematics, science, and computer science. It can be major-related, general, or free elective. Table 4.2 shows the definition and examples of courses belonging to the general education/free electives category. If a course was cross listed as an engineering course and a science (or computer science) course, it was counted as an engineering course in this study.

For the 7th field, the first attempt to discriminate between a general and a disciplinary engineering course was by its title. An engineering course was considered as a general course if the title contained “Introduction to engineering”, “Introduction to engineering design”, “Introduction to engineering profession”, etc. The title of a general engineering course should not contain the name of any specific engineering discipline. For example, “Introduction to mechanical engineering” was counted as a disciplinary course rather than a general course. In most cases, engineering graphics, engineering mechanics, engineering science, and statics were classified as general engineering courses if they were not offered by specific disciplinary majors/departments. If judgment could not be made based on the course title, an engineering course was categorized as a general engineering course if: (1) it appeared in the suggested course sequences of all accredited engineering programs at that institution; and (2) it was not offered by a specific engineering major/department, such as mechanical engineering. A course cross listed as a general and a disciplinary engineering course would be counted as a general engineering course in this study.

Table 4.2 General Education/Free Electives Courses

General Education/ Free Electives	**Definition and Example**
Major-related	Architecture, Computer Graphics Technology, Construction, Drafting, Electronics, Machine and Manufacturing, Management Information System, Naval/Nautical Science, Oceanography, Psychology, Technology
General	Art, History, Humanities, and Social Science courses. Such as Christian Heritage, Economy, English, Exam/Test, History, New Student Orientation, Physical Education, Writing, etc.
Free elective	Chosen from a list of general courses or a list of courses belonging to multiple course categories. The course list includes art/history/humanities/social science courses, and sometimes includes science/math courses. If the course list to be chosen from includes exclusively science courses, it is categorized as a science course (same for engineering, mathematics, and computer science elective course)

First-Year Engineering Course Description

All first-year engineering courses including mandatory, elective, and optional courses were selected for the course description analysis. For an engineering course with missing course description: (1) if it was a laboratory course, as indicated in the course title, it was included in the sample for course content analysis with “conducting experiments in labs” as the default course description; (2) if it was a co-op course, as indicated in the course title, it was included in the analysis with “being an intern during the summer or school year” as the default course description; (3) if it was not a laboratory or co-op course, it was eliminated from the sample of course content analysis. In total, there were 2,222 non-repeated engineering courses with descriptions that could be dissected into meaningful keywords.

Admission and Advising Policies

Information on admission and advising policies relevant to this study includes:

1. The place where first-time incoming students intending to pursue engineering are formally admitted
2. When students are admitted to the college/school/department of engineering
3. When students are admitted to a specific engineering degree program
4. Requirements for admission to major
5. Advising before and after admission to major

Based on the admission and advising policies, nearly all 408 institutions with ABET EAC-accredited engineering programs were classified into one of the three matriculation models. Specifically, 287 (70%), 74 (18%), and 43 (11%) institutions were identified as *Discipline*-, *College*-, and *University*-admitted institutions respectively. Four institutions were left unclassified due to insufficient information on admission and advising policies provided online. Further, based on the schedule and requirements of the first engineering/disciplinary engineering course, institutions were classified using the *Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses* (Table 3.1) developed by Chen and her colleagues (2014). Table 4.3 shows the distribution of 408 institutions in the taxonomy. Figure 4.1 and Figure 4.2 show the distributions of the number of institutions grouped using the taxonomy. Figure 4.3 and Figure 4.4 show the distributions of the number of engineering bachelor's degrees granted at institutions with accredited programs grouped using the taxonomy.

Although institutions with one accredited engineering program accounted for 20% of the sampling institutions, they only granted 2% of the engineering bachelor's degrees in the 2011-12 academic year. In other words, institutions with multiple accredited programs granted 98% of the engineering bachelor's degrees. Particularly, over 60% of the engineering bachelor's degrees were granted at *Discipline*-admitted institutions with multiple accredited programs. As discussed in Section 4.1.1, over 99% of the nation's engineering bachelor's degrees were granted at institutions studied in this research. Therefore, the educational experiences of engineering bachelor's degree recipients at institutions with multiple accredited engineering programs, especially at *Discipline*-admitted institutions with multiple accredited engineering programs, are representative of the experiences of all engineering bachelor's degree recipients nationwide.

Table 4.3 Distribution of 408 Institutions with ABET EAC-Accredited Programs in the Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses

Dimension 1			Dimension 2 and 3					
Discipline	287	70.34%	Multiple programs	229	56.13%	D1*	158	38.73%
						DA*	58	14.22%
						DN* (N≥2/B)	6	1.47%
						D??	7	1.72%
			One program	58	14.22%	D1X	47	11.52%
						DNX (N≥2)	3	0.74%
						D?X	8	1.96%
College	74	18.14%	Multiple programs	69	16.91%	C1*	52	12.75%
						CA*	14	3.43%
						CN* (N≥2/B)	2	0.49%
						C??	1	0.25%
			One program	5	1.23%	C1X	5	1.23%
University	43	10.54%	Multiple programs	24	5.88%	U1*	8	1.96%
						UA*	4	0.98%
						UN* (N≥2/B)	8	1.96%
						U??	4	0.98%
			One program	19	4.66%	U1X	9	2.21%
						UNX (N≥2)	4	0.98%
						U?X	6	1.47%
Undetermined	4	0.98%	Multiple programs	3	0.74%	???	3	0.74%
			One program	1	0.25%	?1X	1	0.25%

Note. See Table 3.1 for the labeling of the taxonomy; * refers to any number or letter; ? refers to the associated dimension in the taxonomy is undetermined; N refers to a number that is greater than or equal to 2, or a letter that comes after B alphabetically or equal to B. Totals may not add to 100 percent due to rounding.

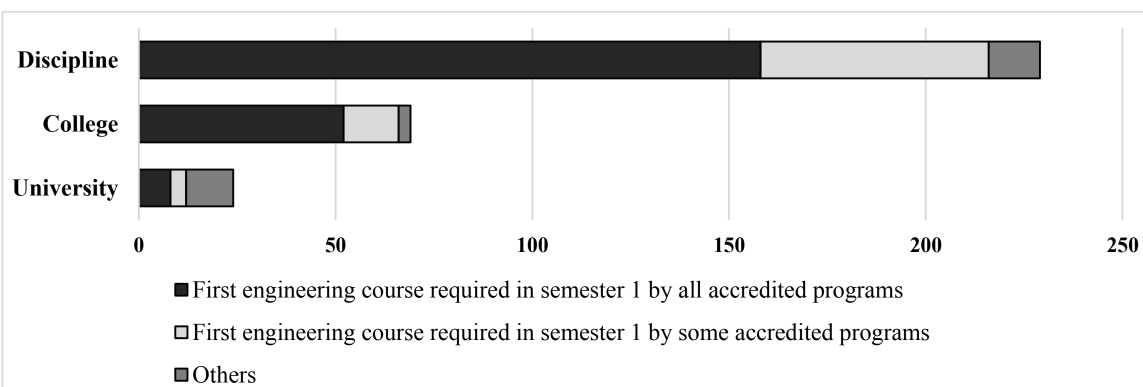

Figure 4.1 Distribution of the Number of Institutions with Multiple ABET EAC-Accredited Programs in the Taxonomy (Number of Institutions = 322)

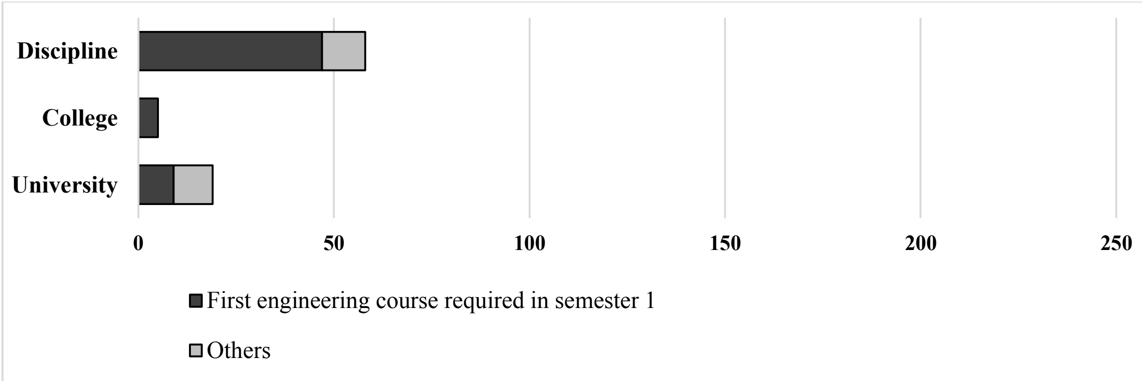

Figure 4.2 Distribution of the Number of Institutions with One ABET EAC-Accredited Program in the Taxonomy (Number of Institutions = 82)

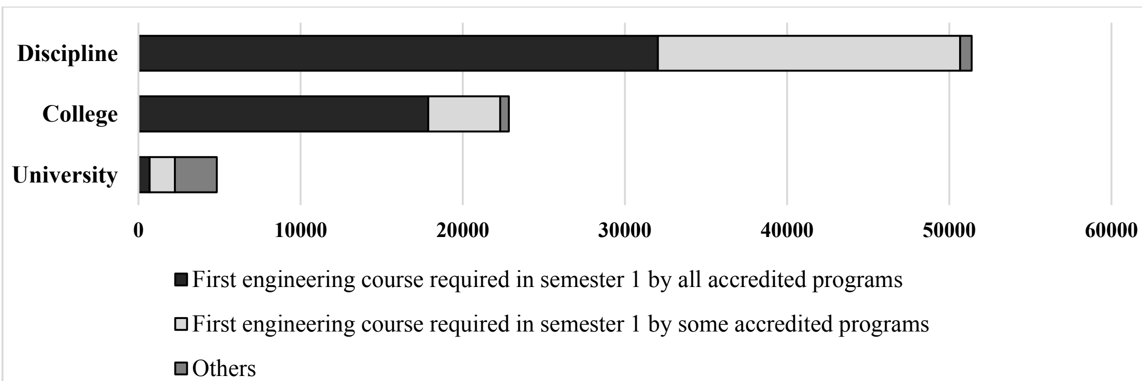

Figure 4.3 Distribution of the Number of Engineering Bachelor's Degrees Granted at Institutions with Multiple ABET EAC-Accredited Programs in the Taxonomy (Number of Institutions = 319)

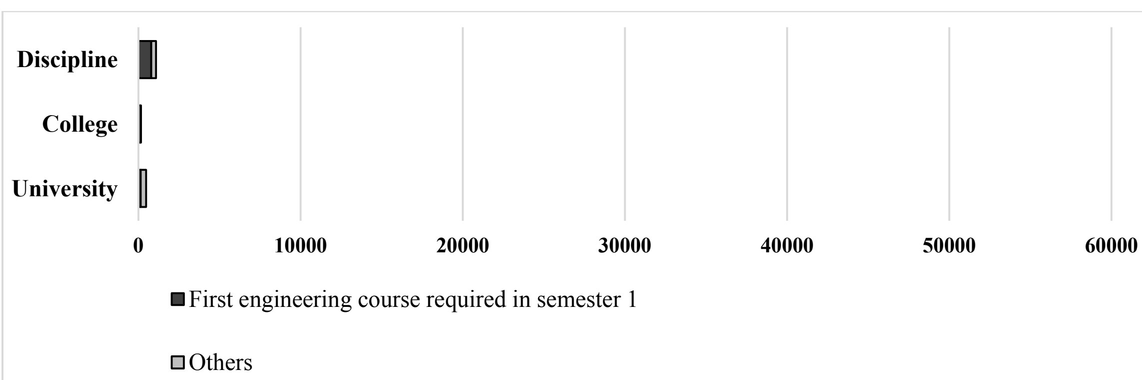

Figure 4.4 Distribution of the Number of Engineering Bachelor's Degrees Granted at Institutions with One ABET EAC-Accredited Program in the Taxonomy (Number of Institutions = 80)

4.2 Analysis

In terms of statistical technique, this study employed descriptive statistics to analyze the first-year engineering curriculum composition, engineering course requirements, engineering course description, institutional characteristics, and their relationships to matriculation models. This approach is similar to the one used by Adelman (1998) and Russell and Stouffer (2005) in their studies of curriculum-related issues. Detailed analyses of the curricula compositions and engineering course keywords are provided below.

4.2.1 Curriculum Composition

This study considered three basic types of academic calendar systems: two, three, and four terms per academic year. As Russell and Stouffer (2005) stressed, programs with different types of academic calendar systems usually arrange courses differently. Consequently, curricula compositions of engineering programs under different calendar systems were analyzed separately in this study. To determine the composition of the current first-year engineering curriculum, this study used the number of credits to measure the proportion of course categories. Since course credit is a proxy measure for time, the proportion of credits measures the relative weights of course categories. For an engineering program, the number of credits per course category was aggregated to calculate the proportion of time spent on each course category. The calculation was performed term-by-term to derive the curriculum composition of an engineering program. Further, for engineering programs adopting the same matriculation model, the average number of credits per course category was calculated for the analysis of curricula compositions by matriculation models. Again, the calculation was performed term-by-term to derive the curriculum composition of a matriculation model.

While calculating course credits, this study followed three rules: (1) if course credits were missing, the associated course was considered to be a zero credit course. If course credits of an entire first-year suggested course sequence were missing, this course sequence was excluded from the study of curriculum composition; (2) if the term in which a course was offered was unavailable, the associated course was considered to be offered in the first term. If the timing information of an entire first-year suggested course sequence was missing, this course sequence was excluded from the study of curriculum composition; and (3) if a course was optional (i.e. recommended but not required), it was excluded from the calculation of the sum of course credits.

Table 4.4 The First Term Suggested Course Sequence for Aerospace Engineering at Arizona State University

Prefix	Title	Credit	Requirement	Category	General/ Disciplinary
CHM 114	General Chemistry for Engineers	4	E 1-1	S	
CHM 116	General Chemistry II	4	E 1-2	S	
ENG 101	First-Year Composition	3	E 2-1	F	
ENG 102	First-Year Composition	3	E 2-2	F	
ENG 105	Advanced First-Year Composition	3	E 2-3	F	
ENG 107	First-Year Composition	3	E 2-4	F	
ENG 108	First-Year Composition	3	E 2-5	F	
–	Humanities, Arts and Design AND Cultural Diversity in the U.S.	3	E 3-1	F	
–	Humanities, Arts and Design AND Global Awareness	3	E 3-2	F	
–	Humanities, Arts and Design AND Historical Awareness	3	E 3-3	F	
MAT 265	Calculus for Engineers I	3	M	M	
FSE 100	Introduction to Engineering	2	M	E	G
ASU 101-MAE	The ASU Experience	1	M	E	D

Source: Arizona State University, 2013 - 2014 Major Map Aerospace Engineering (Aeronautics), BSE

As an example, Table 4.4 provides a suggested course sequence for aerospace engineering program at Arizona State University in the first term (Arizona State University, 2013). The column “Requirement” records whether the course is mandatory, elective, or optional. It also records the group in which an elective course is in. For example, CHM 114 is recorded as “E 1-1” in the column “Requirement”. “E” indicates that CHM 114 is an elective course. The first “1” indicates CHM 114 is in the first group of elective courses. The second “1” indicates CHM 114 is the first elective course in the group. CHM 116 is recorded as “E 1-2”. “E 1” shows that it is an elective course in the first group. “2” indicates CHM 116 is the second elective course in the group. In other words, students can choose between CHM 114 and CHM 116 in the first term. Similarly, ENG 101, ENG 102, ENG 105, ENG 107, and ENG 108 are elective courses belong to the second group of elective courses. Students can choose any one of the courses from the second group. For MAT 265, FSE 100, and ASU 101-MAE, they are mandatory courses and are recorded as “M” in the column “Requirement”. An optional course would be recorded as “O” in the column “Requirement”. The column “Category” indicates the category in which a course is categorized. Engineering, mathematics, science, computer science, and general education/free electives courses are recorded as “E”, “M”, “S”, “C”, and “F” respectively. For an engineering course, the column “General/Disciplinary” indicates if it is a general course or a disciplinary course. “G” means general and “D” means disciplinary. Measured by course credits, the first-term curriculum for aerospace engineering program at Arizona State University is comprised by 3 credits (19%) of engineering courses, 3 credits (19%) of mathematics courses, 4 credits (25%) of science courses, 0 credit of computer science course, and 6 credits (38%) of general education/free electives courses. For engineering courses, 2 credits (67%) come from mandatory, general engineering courses, and 1 credit (33%) comes from mandatory, disciplinary engineering courses.

4.2.2 Keywords of Course Descriptions

This study followed four steps to analyze the descriptions of first-year engineering courses. First, description of each engineering course was dissected into keywords. Keywords were extracted as specific as possible despite that both broad and narrow entries existed. For example, ENGR 102 Computer Aided Design is offered to first-year students in all accredited engineering programs at Alfred University. The course description of ENGR 102 is:

"An introduction to 3D conceptualization, computer aided solid modeling and design, engineering drawings, and simulation using SolidWorks." (Alfred University, 2013, p. 279)

This study extracted the following keywords from ENGR 102: 3D conceptualization, computer aided solid modeling and design, engineering drawings, simulation using SolidWorks.

Second, this study resolved differences in the use of terminology after extracting all keywords for the first time. A list of keywords sorted in alphabetical order was created to facilitate the process. For example, keywords "2D CAD software", "2D CAD", "2-D CAD", and "two dimensional computer-aided design" were all renamed as "2-D CAD".

Third, keywords extracted from the course descriptions were classified using a revised *First-Year Engineering Course Classification Scheme*. The original classification scheme was developed by Reid and his colleagues (2013) recently through analysis of syllabi and discussion with faculty members in focus groups and in a Delphi study. There are four levels of topics in the scheme. The first level includes eight main topics: academic advising, communication, design, engineering specific tech/tools, engineering profession, global interest, latent curriculum/professional skills, math skills and applications (Reid, Reeping, et al., 2013). There are three levels of topics under each main topic: topic, sub-topic, and specific topic. For example, keyword "circuits" is classified as *Engineering Specific Tech/Tools →Engineering Skills →Circuits* with ID *ESTT I.B.0*. Here, *Engineering Specific Tech/Tools* is the main topic, *Engineering Skills* is the topic, and *Circuits* is the sub-topic. Specific topic is not defined in this example. In the ID, *ESTT* is short for *Engineering Specific Tech/Tools*. *I* means topic I, *B* means sub-topic B, and *0* means a missing specific topic. While adopting the scheme to classify keywords, this study also tested the applicability of this scheme to first-year engineering courses nationwide. Although the scheme is derived from syllabi of general engineering courses instead of disciplinary engineering courses, it allows discipline-specific concepts to be classified into some of its categories. The majority of keywords extracted from course descriptions were classified by the scheme. A few keywords left unclassified were marked with notes. Afterwards, this study modified the classification scheme to allow unclassified keywords to be categorized by the revised scheme. Appendix A describes the original scheme with definitions. **Error! Reference source not found.** shows the revised scheme with frequently listed keywords. In **Error! Reference source not found.**, revisions to the original scheme are highlighted in bold.

Noticeably, this study classified some of the keywords based solely on the keywords themselves. For instance, keyword "Java" was classified as *ESTT II.A.2 Engineering Specific Tech/Tools →Software →Programming →Java* in which *Engineering Specific Tech/Tools* was the main topic, *Software* was the topic, *Programming* was the sub-topic, and *Java* was the specific topic. However, some keywords could not be classified properly until they were examined in the course description. For example, keyword "report" could not be classified based on the keyword alone. It was examined in the associated course description to determine if it was a lab report (classified as COMM II.A.2) or an engineering project report (COMM II.A.3). If the course description did not provide information on the type of report it belonged to, the keyword "report" would be classified as a written report (COMM II.A.0) – a more generalized category than COMM II.A.2 or COMM II.A.3 with undefined specific topic. Sometimes a keyword was classified into more than one category. For example, keyword "a group design project" was classified as both *DESN I.F.2 Design →Engineering Design Process →Authentic Design →Design Projects* and *PROF III.0.0 Latent Curriculum/Professional Skills →Teamwork*. Using ENGR 102 offered at Alfred University as an example, Table 4.5 shows the placement of keywords in the revised scheme.

Table 4.5 Classification of Keywords of ENGR 102 Offered at Alfred University

Keyword	**ID**	**Main Topic →Topic →Sub-Topic →Specific Topic**
3D conceptualization	ESTT I.E.1	Engineering Specific Tech/Tools →Engineering Skills →Graphics →3-D Visualization
Computer aided solid modeling and design	ESTT II.C.0	Engineering Specific Tech/Tools →Software →Computer Aided Design
Engineering drawings	ESTT I.E.0	Engineering Specific Tech/Tools →Engineering Skills →Graphics
Simulation using SolidWorks	ESTT II.C.1	Engineering Specific Tech/Tools →Software →Computer Aided Design →Solid Works

After classifying all keywords using the revised scheme, the last step was to examine the frequency of occurrence of each topic, and to analyze the most frequently listed topics. Using the frequency data, this study attempted to answer the following questions:

1. The average number of categories listed per first-year engineering course description.
2. The average number of categories listed in the first-year engineering course descriptions per institution, and how the number varies by institutions with different matriculation models.
3. The most and the least frequently listed categories in the first-year engineering course descriptions, and how these categories vary by institutions with different matriculation models.

CHAPTER 5. RESULTS AND DISCUSSION

This chapter presents the following results with discussion:

1. The composition of the first-year engineering curriculum and the composition of first-year engineering courses. First, the compositions of all accredited engineering programs are given. Second, the compositions of engineering programs grouped by matriculation models are presented. Third, the compositions of engineering programs at institutions with multiple accredited programs are compared by matriculation models. Similarly, the compositions of engineering programs at institutions with one accredited program are compared by matriculation models.
2. The time when the first engineering course is required and the time when the first disciplinary engineering course is required. Course schedules of engineering programs at institutions with multiple accredited programs are compared by matriculation models. Subsequently, course schedules of engineering programs at institutions with one accredited program are compared by matriculation models.
3. The frequency of topics listed in the first-year engineering course descriptions. First, the frequency list of topics of all engineering courses are given. Second, the frequency list of topics at the institution level is provided. Also, the frequently listed categories of institutions with different matriculation models are compared.
4. Institutional characteristics are compared by matriculation models.

5.1 First-Year Engineering Curriculum Composition and Engineering Course Composition

Among 1,969 non-repeated ABET EAC-accredited programs, first-year suggested course sequence of 74 programs could not be found online. Another 22 programs' course sequences were available but information on course credits was missing. Accordingly, the final sample size for the analysis of curriculum composition was 1,873 accredited engineering programs, accounting for 95% of all ABET EAC-accredited programs.

Results of the curriculum composition and engineering course composition are presented at three levels, as Figure 5.1 shows. At the first level, this study analyzed the compositions of all accredited engineering programs. Results are presented separately for engineering programs under different calendar systems. At the second level, engineering programs were grouped into three categories by matriculation models. The compositions of engineering programs with different matriculation models were analyzed. For each matriculation model, results are presented separately for engineering programs under different calendar systems. At the third level, engineering programs were divided into two groups. The first group of programs was offered at institutions with multiple accredited programs. The second group of programs was offered at institutions with only one accredited program. Each group was further divided into three subgroups by matriculation models. For each subgroup, results are presented separately for engineering programs under different calendar systems. Table 5.1 presents the number of engineering programs of each group at three levels of grouping.

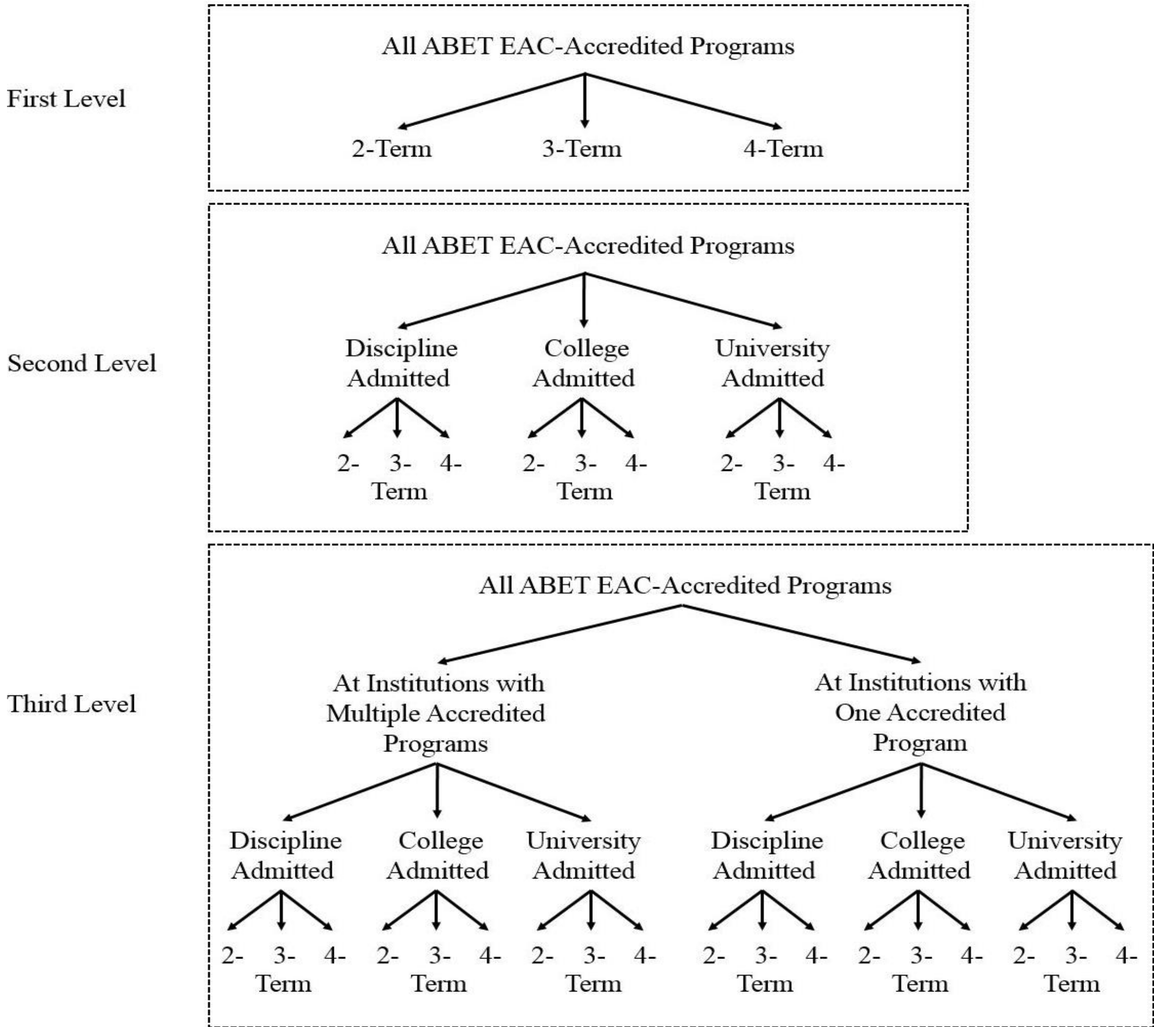

Figure 5.1 Three Levels of Analysis of the First-Year Curriculum Composition and Engineering Course Composition

Table 5.1 ABET EAC-Accredited Programs Distributed by Matriculation Models and Academic Calendar Systems

Matriculation Model	All Institutions				Institutions with Multiple Accredited Programs			Institutions with One Accredited Program		
	D	**C**	**U**	**TBD**	**D**	**C**	**U**	**D**	**C**	**U**
2-term	1131	420	98	2	1085	415	86	46	5	12
3-term	172	29	19	–	168	29	18	4	–	1
4-term	2	–	–	–	2	–	–	–	–	–
Sample total	1305	449	117	2	1255	444	104	50	5	13
Total	1344	469	145	11	1286	464	126	58	5	19
Data coverage	97.10%	95.74%	80.69%	–	97.59%	95.69%	82.54%	86.21%	100.00%	68.42%

Note. See Table 3.1 for the labeling of the taxonomy.

5.1.1 Curriculum Composition of Engineering Programs

At the first level of analysis, the curriculum composition of all ABET EAC-accredited programs was considered (Figure 5.2). As Table 5.1 shows, in 1,873 engineering programs, 1,651 (88%) programs offered 2-term suggested course sequences, 220 (12%) programs offered 3-term course sequences, and 2 programs offered 4-term course sequences. Only two programs offered 4-term course sequences. Their curricula compositions are shown in this chapter for completeness, but discussion is focused on the curricula compositions of 2- and 3-term course sequences only. Figure 5.3, Figure 5.4, and Figure 5.5 present how the average first-year curricula of 2-, 3-, and 4-term engineering programs were comprised by five course categories respectively. The proportion of course categories was measured by course credits. Figure 5.6, Figure 5.7, and Figure 5.8 present the compositions of first-year engineering courses (general versus disciplinary, mandatory versus elective) of 2-, 3-, and 4-term engineering programs respectively.

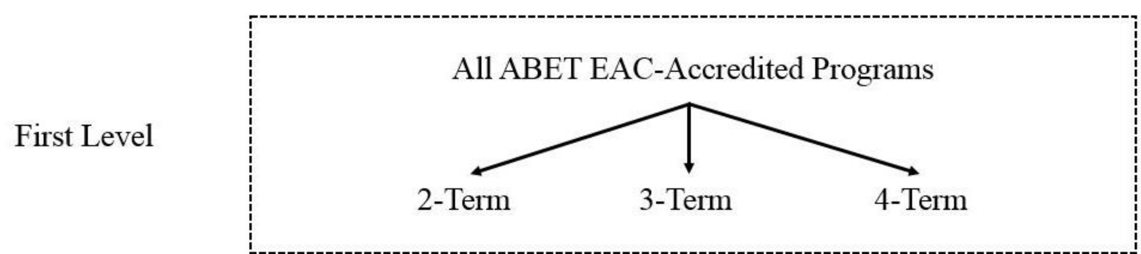

Figure 5.2 The First Level of Analysis of the First-Year Curriculum Composition and Engineering Course Composition

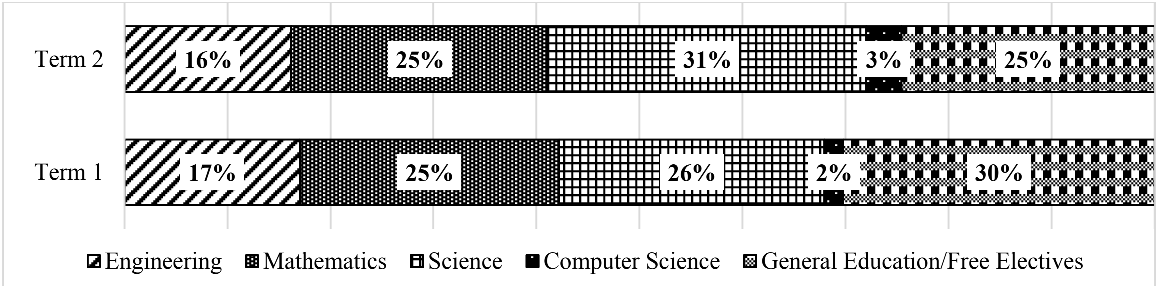

Figure 5.3 First-year Course Composition of 2-Term ABET EAC-Accredited Engineering Programs (Number of Institutions = 1,651)

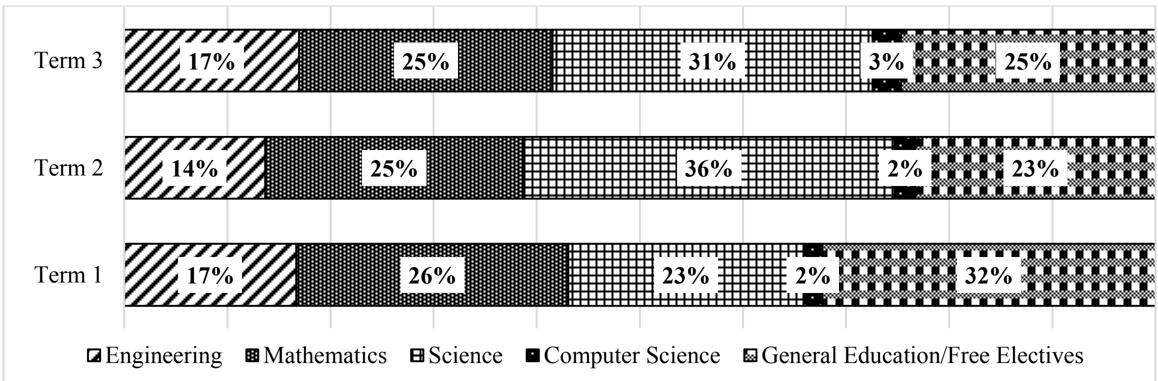

Figure 5.4 First-year Course Composition of 3-Term ABET EAC-Accredited Engineering Programs (Number of Institutions = 220)

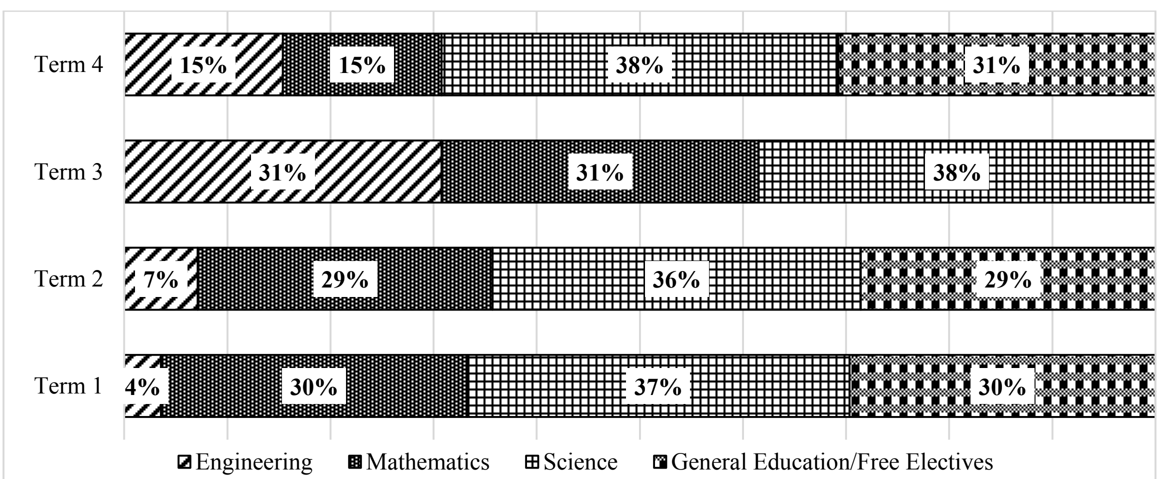

Figure 5.5 First-year Course Composition of 4-Term ABET EAC-Accredited Engineering Programs (Number of Institutions = 2)

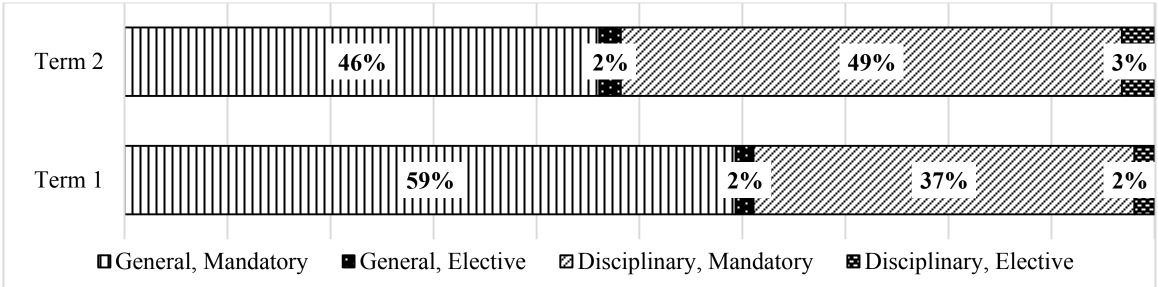

Figure 5.6 First-year Engineering Course Composition of 2-Term ABET EAC-Accredited Engineering Programs

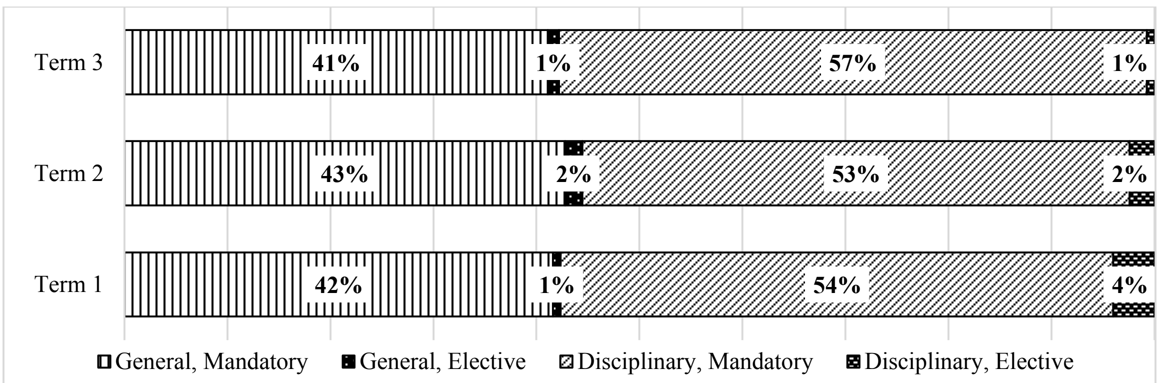

Figure 5.7 First-year Engineering Course Composition of 3-Term ABET EAC-Accredited Engineering Programs

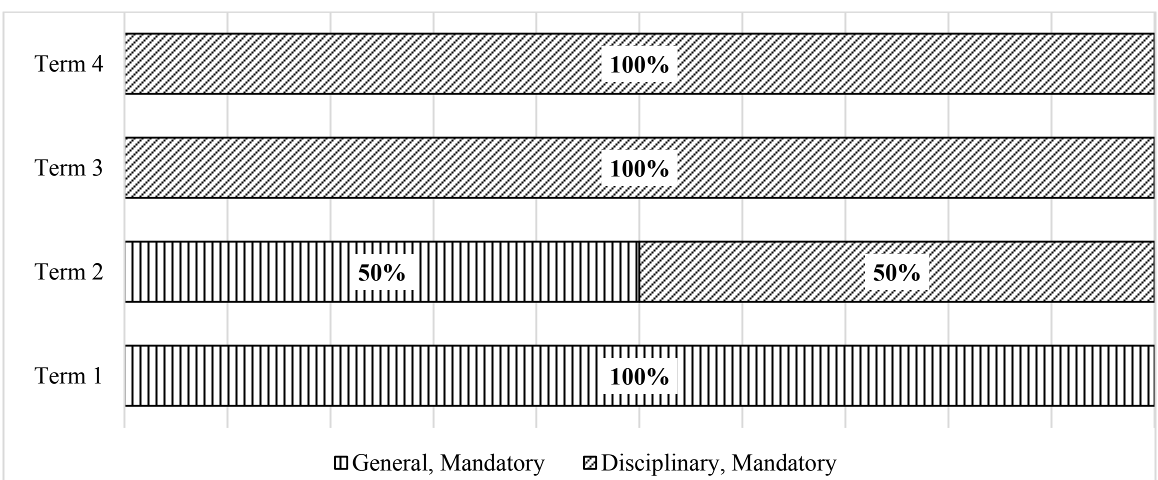

Figure 5.8 First-year Engineering Course Composition of 4-Term ABET EAC-Accredited Engineering Programs

For the first-year curriculum composition of 2-term course sequences (Figure 5.3), the percentages of engineering, mathematics, and computer science courses did not change much from term 1 to term 2. On average, engineering courses took up 16-17% of total course credits. Mathematics courses accounted for 25% of course credits. Computer science courses only took up 2-3% of total course credits. The proportion of science courses increased significantly from 26% to 31% in term 2. Conversely, the percentage of general education and free elective courses dropped from 30% to 25% in term 2.

For the first-year curriculum composition of 3-term course sequences (Figure 5.4), the percentages of mathematics and computer science courses remained stable across terms. Similar to their proportions in 2-term sequences, mathematics courses took up a quarter of total course credits, and computer science courses accounted for 2-3% of course credits. Surprisingly, the percentage of engineering courses dropped from 17% to 14% in term 2, then rose back to 17% in term 3. The percentage of science courses increased drastically from 23% to 36% in term 2, then decreased to 31% in term 3. Conversely, the percentage of general education and free elective courses dropped significantly from 32% to 23% in term 2, then went up slightly to 25% in term 3.

For the first-year engineering course composition of 2-term course sequences (Figure 5.6), mandatory courses comprised 95-96% of the engineering course credits. General mandatory engineering courses accounted for 59% of the engineering course credits in term 1, followed by disciplinary mandatory engineering courses (37%). In term 2, engineering programs included more disciplinary elements in the curricula. The percentage of general mandatory courses shrank significantly to 46% while the percentage of disciplinary mandatory courses increased to 49%. Elective engineering courses including general and disciplinary courses accounted for only 4-5% of the engineering course credits.

For the first-year engineering course composition of 3-term course sequences (Figure 5.7), mandatory courses still took up most of the engineering course credits (95-98%). Unlike the course composition of 2-term course sequences, the percentages of general mandatory courses and disciplinary mandatory engineering courses remained stable across terms, ranging from 41% to 43% and from 53% to 57% respectively. Still, elective engineering courses accounted for a very small proportion of the engineering course credits per term (2-5%).

Overall, mathematics courses accounted for 25% of total credit hours in the first year. Computer science courses accounted for only 2-3% of total credit hours. The percentages of mathematics courses and computer science courses remained stable from term to term. Together, science courses and general education/free electives courses comprised 55-59% of the first-year credit hours. The proportion of science courses increased by term, while the percentage of general education/free electives courses decreased. General education/free electives courses accounted for the largest proportion of total credits in the first term, taking up at least 30% of total credit hours. Their percentage was exceeded by the percentage of science courses in the following term(s). Engineering courses took up 14-17% of the first-year credit hours despite small changes in the percentage across terms.

While taking a closer look at the composition of first-year engineering course, mandatory courses made up most of the engineering course credits, leaving little room for students to choose elective courses. Differences in the arrangement and proportion of general versus disciplinary engineering courses existed between engineering programs offering 2- and 3-term course sequences. On average, engineering programs offering 2-term sequences put more emphasis on general engineering knowledge in the first term, then switched to disciplinary-specific knowledge in the second term. Comparatively, the arrangement of general versus disciplinary engineering courses was more consistent in engineering programs offering 3-term sequences. Disciplinary courses always took up 10-15% more credit hours than general engineering courses. On average, engineering programs offering 2-term sequences always had a higher percentage of general engineering courses (and a lower percentage of disciplinary engineering courses) than engineering programs offering 3-term sequences.

This study revealed that over half of the first-year course credits were accounted for by mathematics and science courses. The result was in accordance with previous research that mathematics and science still formed the foundation in the early engineering curricula after ABET criteria EC2000 was implemented (Lattuca, et al., 2006). Both Russell and Stouffer (2005) and Sheppard et al. (2009) highlighted the course arrangement of engineering programs. Students typically begin with mathematics, science, and general courses in the first year, and start taking engineering sequence and specialized technical courses in their sophomore year. By their junior and senior years, students will have completed the mathematics and science requirements, and focus on technical courses particular to their selected engineering subfield. Findings of this study supported the first part of their argument. The percentages of mathematics, science, and general courses in the first-year engineering curriculum were much higher than the percentages in the four-year civil engineering curriculum shown in Russell and Stouffer's study (2005), indicating that mathematics, science, and general courses accounted for a much larger proportion in the first year than in the following years. Although engineering and computer science courses only took up 16-20% of total first-year credit hours, it was anticipated that their proportion would increase drastically in the following years.

Meanwhile, this study found a surprisingly low percentage of elective engineering courses required in the first year. This finding suggests that engineering programs prefer a highly structured curriculum in the first year to equip students with a common body of knowledge in engineering, leaving little room for students to choose engineering courses tailor to their own interests.

5.1.2 Curriculum Composition by Matriculation Model

At the second level of the analysis of curriculum composition, this study examined the differences in curricula compositions among engineering programs with different matriculation models. Firstly, 1,873 ABET EAC-accredited programs were grouped into *Discipline*-admitted programs, *College*-admitted programs, and *University*-admitted programs based on the matriculation model adopted by their associated institutions. Further, engineering programs of each matriculation model were grouped by the academic calendar system they used. Figure 5.9 shows the grouping of engineering programs at the second level of analysis. For each group of engineering programs, an average number of credits per course category was calculated to study the first-year engineering curriculum composition.

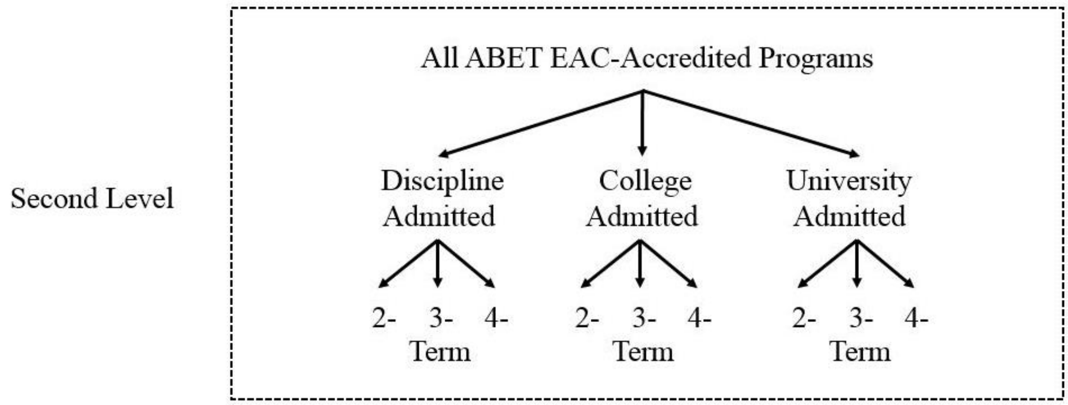

Figure 5.9 The Second Level of Analysis of the First-Year Curriculum Composition and Engineering Course Composition

As Table 5.1 shows, *Discipline*-admitted institutions had the largest number of engineering programs, possessing 70% (1305/1873) of the accredited programs in the sample. The percentages of *College*-admitted programs and *University*-admitted programs were 24% and 6% respectively. Notably, over 95% of the *Discipline*-admitted programs and *College*-admitted programs provided first-year suggested course sequences online, whereas only 81% of the *University*-admitted programs did so. One implication is that first-year students at *University*-admitted institutions have more curricular freedom but less formal written guidance in course selection to meet the admission requirements of engineering programs.

Among 1,651 engineering programs with accessible 2-term suggested course sequences, 1,131 programs were *Discipline*-admitted, 420 programs were *College*-admitted, and 98 programs were *University*-admitted. Figure 5.10, Figure 5.11, and Figure 5.12 present the first-year curricula compositions of *Discipline*-admitted, *College*-admitted, and *University*-admitted engineering programs with 2-term course sequences respectively. For engineering programs with accessible 3-term suggested course sequences, 172 programs were *Discipline*-admitted, 29 programs were *College*-admitted, and 19 programs were *University*-admitted. Figure 5.13, Figure 5.14, and Figure 5.15 present the first-year curricula compositions of these engineering programs respectively. Correspondingly, Figure 5.16, Figure 5.17, and Figure 5.18 present the compositions of first-year engineering courses of programs offering 2-term suggested course sequences. Figure 5.19, Figure 5.20, and Figure 5.21 present the first-year engineering course compositions of programs offering 3-term suggested course sequences. The two programs offering 4-term course sequences were *Discipline*-admitted. Their curricula compositions are already shown in Figure 5.5 and Figure 5.8. Again, discussion is focused on the curricula compositions of 2- and 3-term course sequences only.

Firstly, the first-year engineering curriculum comprised by five course categories is examined. For *Discipline*-admitted programs offering 2-term course sequences (Figure 5.10), their average first-year curriculum composition was quite similar to the curriculum composition of all programs offering 2-term course sequences (Figure 5.3). The percentages of engineering and mathematics courses accounted for 17% and 25% of total first-year course credits respectively. Science courses took up 25% of total course credits in the first term, and took up 30% in the second term. General education and free elective courses accounted for a high percentage of course credits. Their proportion decreased from 31% to 24% in the second term. Although computer science courses took up only 2% in the first term, their percentage doubled in the second term. For *College*-admitted programs offering 2-term course sequences (Figure 5.11), their curriculum composition was similar to the curriculum composition of *Discipline*-admitted programs (Figure 5.10) except for higher percentages of science courses and lower percentages of general education/free elective courses in both terms. For *University*-admitted programs offering 2-term course sequences (Figure 5.12), they had a much lower percentage of engineering courses. Despite a slight increase in the second term, the percentage of engineering courses was 3-6% lower than the percentage in the curriculum composition of all programs offering 2-term course sequences (Figure 5.3). In contrast, *University*-admitted programs had a much higher percentage of general education and free elective courses. Seemingly *University*-admitted institutions allow first-year students to choose courses with more freedom. Engineering programs offered at *University*-admitted institutions do not expose students to engineering through instruction as much as engineering programs at *Discipline*-admitted and *College*-admitted institutions.

For *Discipline*-admitted programs offering 3-term course sequences (Figure 5.13), their average first-year curriculum composition was similar to the curriculum composition of all programs offering 3-term course sequences (Figure 5.4) except a lower percentage of engineering courses and a higher percentage of science courses in the third term. For *College*-admitted programs offering 3-term course sequences (Figure 5.14), they had surprisingly high percentages of engineering courses, rising from 25% to 35% from term 1 to term 3. In comparison, mathematics courses only accounted for about 20% of total credit hours, roughly 5% lower than the average percentage in the curriculum composition of all programs offering 3-term course sequences (Figure 5.4). Meanwhile, science courses only took up 11% of course credits in the third term. A careful examination of the curriculum data indicated that the 29 *College*-admitted programs offering 3-term course sequences belonged to five institutions only. Seventeen accredited programs were offered at two institutions with high proportions of engineering courses required in the first year. Therefore, the curriculum composition of *College*-admitted programs offering 3-term course sequences was highly influenced by the engineering curricula structures of two institutions. For *University*-admitted programs offering 3-term course sequences (Figure 5.15), they had a much lower percentage of engineering courses and significantly higher percentages of mathematics, science, and general education/free elective courses across terms, as compared with all programs offering 3-term course sequences (Figure 5.4). Although the percentage of engineering courses increased rapidly from 2% to 7% then to 12% by term, it was still 5-15% lower than the percentage in the course composition of all accredited programs with 3-term course sequences (Figure 5.4).

Secondly, the first-year engineering course composition is analyzed. For *Discipline*-admitted programs offering 2-term course sequences (Figure 5.16), mandatory courses took up 96-97% of total first-year engineering course credits. Compared to all programs offering 2-term course sequences (Figure 5.6), *Discipline*-admitted programs required 7-8% more disciplinary courses in the first year. For *College*-admitted programs offering 2-term course sequences (Figure 5.17), they required significantly higher percentages of general engineering courses than *Discipline*-admitted programs in both terms (Figure 5.16). The difference in percentage was 23-27% in the first year. Correspondingly, *College*-admitted programs required many fewer credit hours to be devoted to disciplinary engineering courses, as compared to *Discipline*-admitted programs. With specific focus on elective engineering courses, *College*-admitted programs had twice as many credit hours spent on elective courses as *Discipline*-admitted programs, providing more freedom for students to determine what they were interested in within engineering subfields. For *University*-admitted programs offering 2-term course sequences (Figure 5.18), their engineering course composition was similar to the composition of *College*-admitted programs (Figure 5.17), except an even higher percentage of general engineering courses required in the first year.

Discipline-admitted programs offering 3-term course sequences (Figure 5.19) had a significantly lower percentage of general engineering courses than all programs offering 3-term course sequences (Figure 5.7). Correspondingly, the percentage of disciplinary engineering courses was 6-9% higher. For *College*-admitted programs offering 3-term course sequences (Figure 5.20), they had a much higher percentage of general engineering courses and a significantly lower percentage of disciplinary engineering courses than *Discipline*-admitted programs. Nevertheless, the number of engineering course credits of disciplinary engineering courses increased rapidly across terms, from 20% to 26% then to 40% in the third term. In comparison, the percentage of disciplinary engineering courses stayed almost the same across terms for *Discipline*-admitted programs. For *University*-admitted programs offering 3-term course sequences (Figure 5.21), engineering course composition seemed abnormal, as compared to *University*-admitted programs offering 2-term sequences (Figure 5.18). While over 60% of credit hours was accounted for by general engineering courses for 2-term programs, the percentage was no more than 26% for 3-term programs. An examination of the curriculum data showed that only eleven *University*-admitted, 3-term engineering programs required engineering courses in the first year, and only four of them required engineering courses in the first term. Consequently, the engineering course composition was representative of the curricula of eleven engineering programs at most.

In sum, *Discipline*- and *College*-admitted engineering programs offered a significantly higher percentage of engineering courses and a lower percentage of general education/free elective courses than *University*-admitted programs. Nonetheless, the increase in the percentage of engineering courses by term was much larger for *University*-admitted programs, with a concomitant rapid decrease in the percentage of general education/free elective courses. Particularly for the composition of engineering courses, *Discipline*-admitted engineering programs generally required a much lower percentage of general engineering courses than *College*- and *University*-admitted programs. Correspondingly, *Discipline*-admitted programs required a significantly higher percentage of disciplinary engineering courses in the first year. Overall, the percentage of general engineering courses decreased whereas the percentage of disciplinary engineering courses increased by term for engineering programs with any type of matriculation model.

While Sheppard and her colleagues (2009) claimed that engineering programs shared "a remarkably homogeneous curriculum" (p. 11) based on case studies of the engineering curriculum structure, results of this study suggest that first-year engineering curricula compositions vary by matriculation models. First-year students intending to pursue engineering in *University*-admitted programs are given less exposure to the engineering profession as evidenced by a smaller proportion of engineering courses in the curriculum, comparing to students in *Discipline*-admitted and *College*-admitted programs. As CAEE (Atman, et al., 2010) highlighted, "programs that expose students to engineering experiences and/or projects early might have a greater chance of both enticing students to persist and interesting them in specific subfields of engineering" (p. 31). If Atman and her colleagues are correct, engineering students in *University*-admitted programs would be expected to have a lower persistence rate than engineering students in *Discipline*-admitted and *College*-admitted programs. This inference coincides with the findings of Orr and her colleagues (2012) in a recent study. They found that first-time engineering students in *University*-admitted programs had a much lower persistence rate than students in *Discipline*-admitted and *College*-admitted programs.

Although *University*-admitted programs did not require first-year students to take as many engineering credits as *Discipline*-admitted and *College*-admitted programs, they provided a diverse first-year engineering curriculum characterized by a significantly higher percentage of general education/free elective courses. An advantage of a high proportion of elective courses is that it allows students who are undetermined to clarify their interests. Also, it lowers the barriers for transfer students to migrate into engineering by accepting a wide variety of courses as eligible gateway courses to enter the engineering programs. In fact, findings of Orr et al. (2012) acknowledged the advantages of *University*-admitted programs over *Discipline*- and *College*-admitted programs in attracting transfer students. Over 45% of the engineering graduates in *University*-admitted programs was transfer students, which was much higher than the percentages in *Discipline*-admitted programs (29%) and in *College*-admitted programs (14%).

Last but not least, differences in the percentages of general versus disciplinary engineering courses among *Discipline*-, *College*-, and *University*-admitted engineering programs reflect the distinct characteristics of matriculation models. With the highest percentage of disciplinary engineering courses, *Discipline*-admitted programs aim to establish a direct and clear connection between students' personal interests and the career path in their declared discipline. Students either confirm their choice of major or switch to a major that better fits their interests. With high percentages of general engineering courses, *College*- and *University*-admitted programs intend to increase students' understanding of the engineering profession in general, and expose students to various engineering subfields before they make a formal decision on major selection. Despite difference in the emphasis of general versus disciplinary engineering knowledge, engineering programs of all matriculation models increased the proportion of disciplinary engineering courses by term. One implication is that incoming students who expect to graduate within four years need to determine their engineering major and prepare to take relevant disciplinary courses as early as possible in order to stay on track.

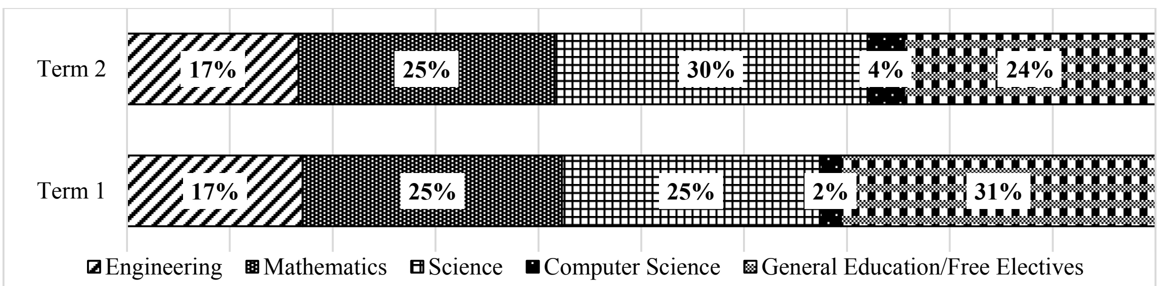

Figure 5.10 First-year Course Composition of 2-Term, Discipline-Admitted Programs (Number of Institutions = 1,131)

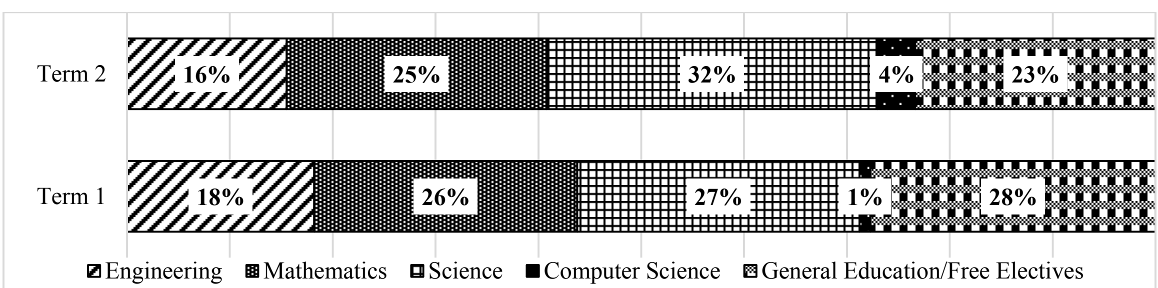

Figure 5.11 First-year Course Composition of 2-Term, College-Admitted Programs (Number of Institutions = 420)

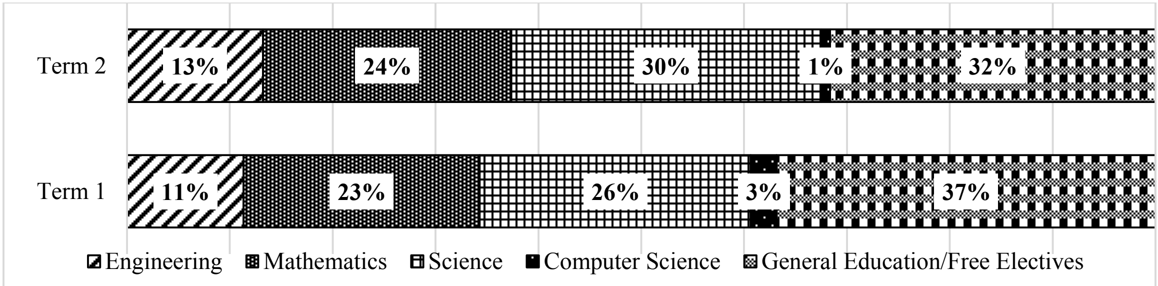

Figure 5.12 First-year Course Composition of 2-Term, University-Admitted Programs (Number of Institutions = 98)

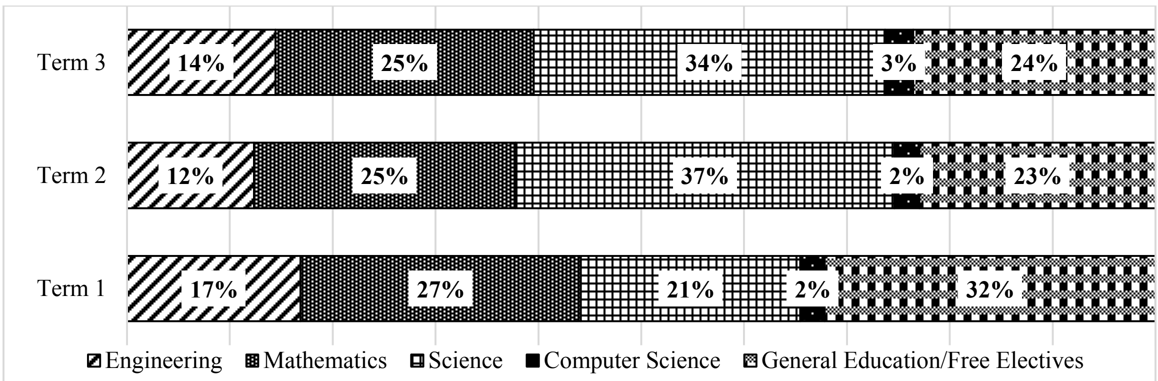

Figure 5.13 First-year Course Composition of 3-Term, Discipline-Admitted Programs (Number of Institutions = 172)

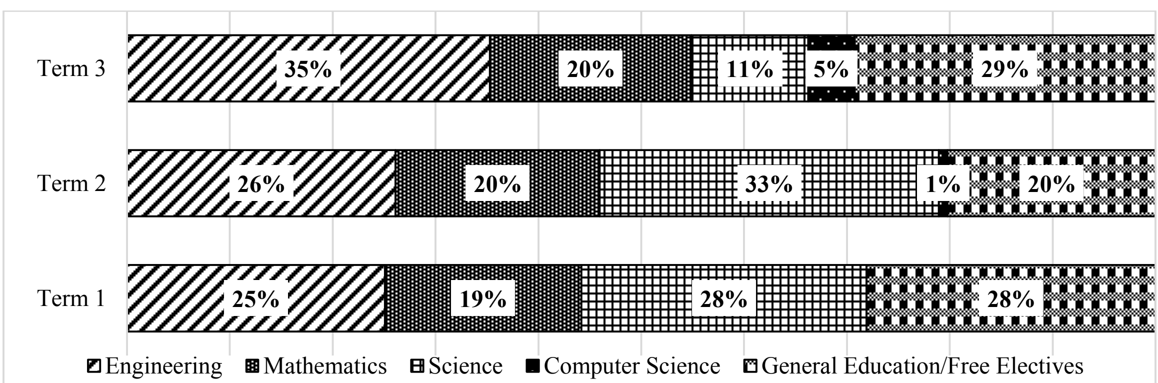

Figure 5.14 First-year Course Composition of 3-Term, College-Admitted Programs (Number of Institutions = 29)

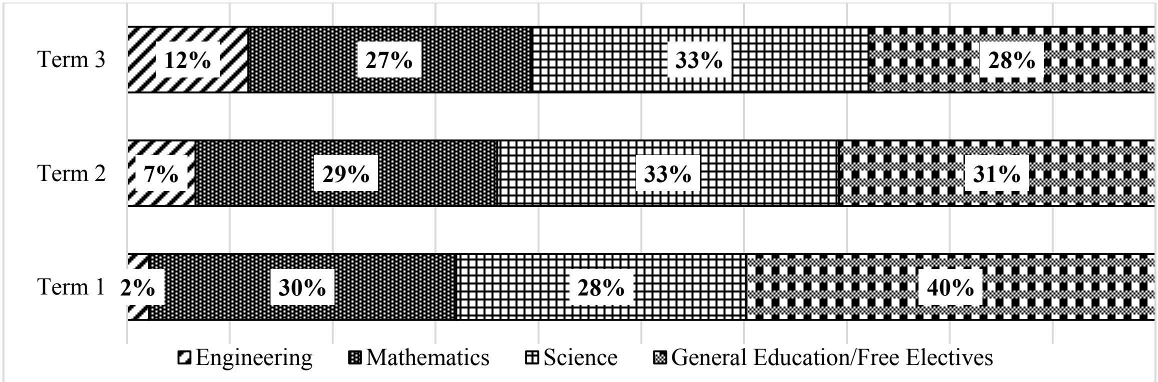

Figure 5.15 First-year Course Composition of 3-Term, University-Admitted Programs (Number of Institutions = 19)

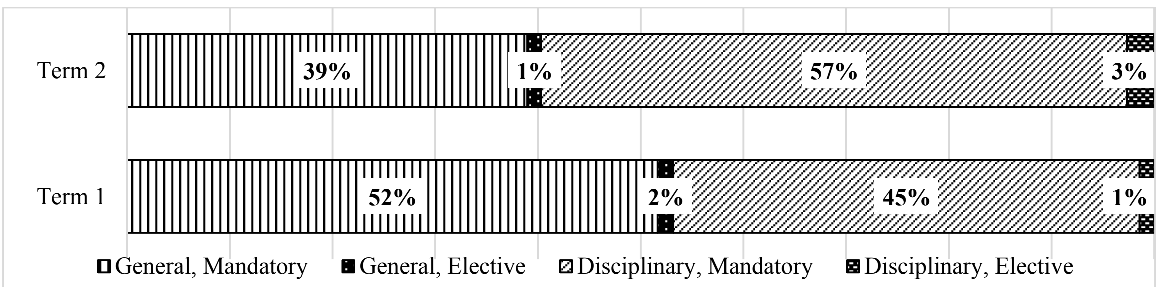

Figure 5.16 First-year Engineering Course Composition of 2-Term, Discipline-Admitted Programs

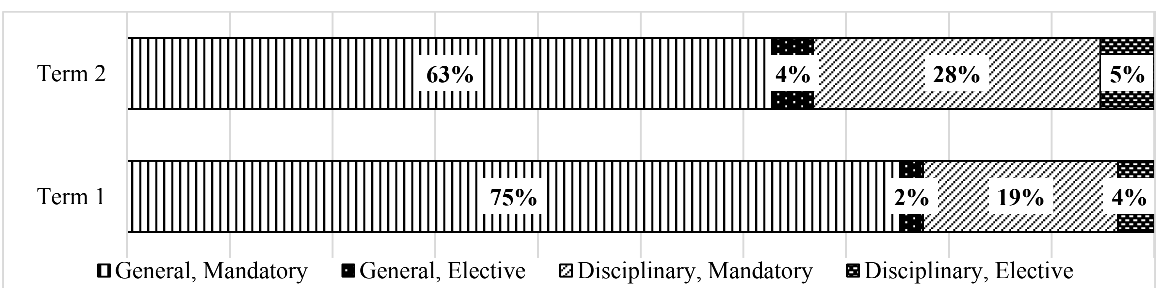

Figure 5.17 First-year Engineering Course Composition of 2-Term, College-Admitted Programs

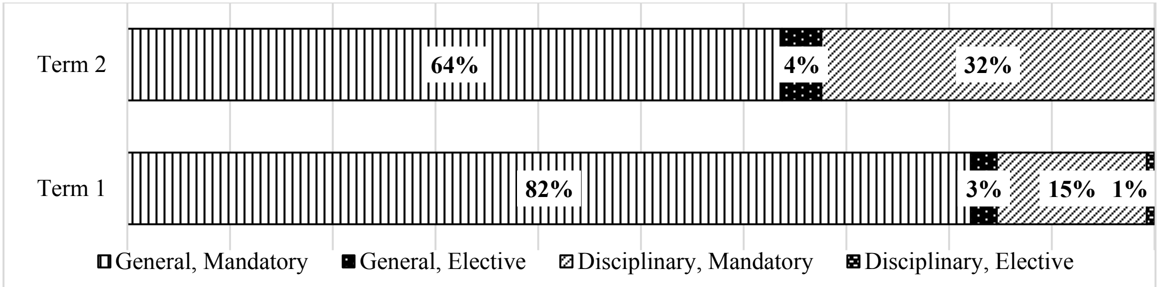

Figure 5.18 First-year Engineering Course Composition of 2-Term, University-Admitted Programs

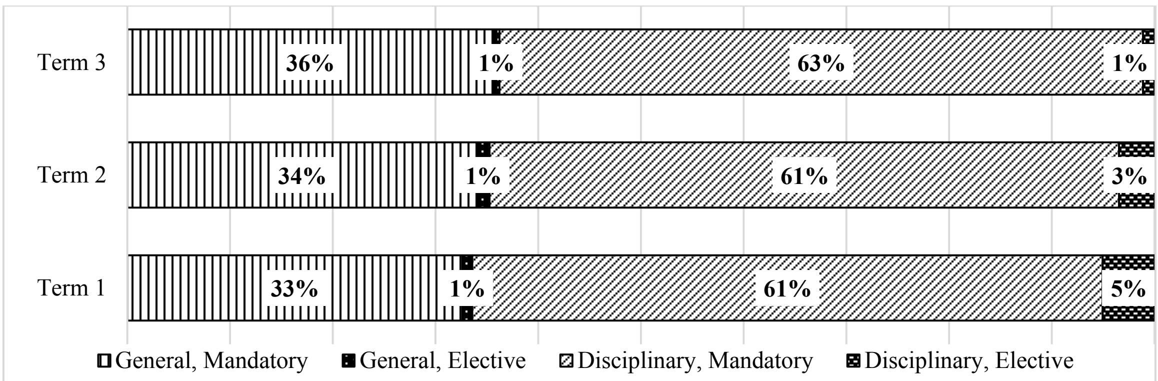

Figure 5.19 First-year Engineering Course Composition of 3-Term, Discipline-Admitted Programs

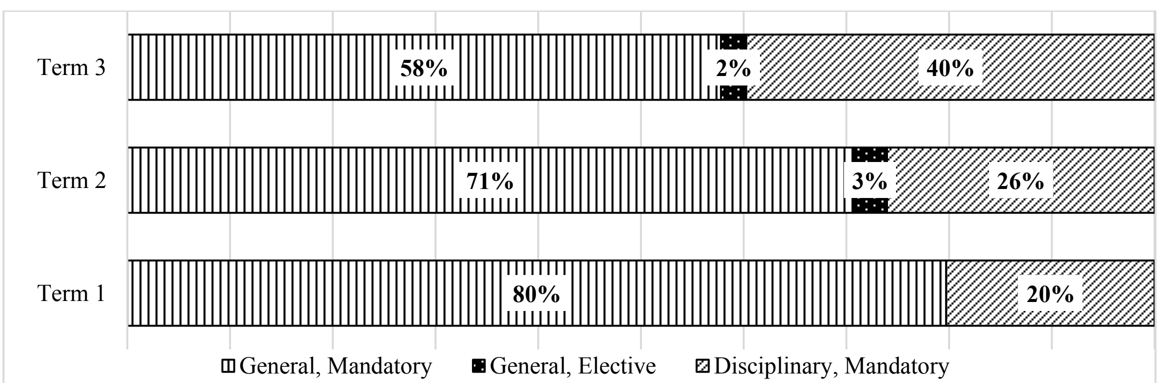

Figure 5.20 First-year Engineering Course Composition of 3-Term, College-Admitted Programs

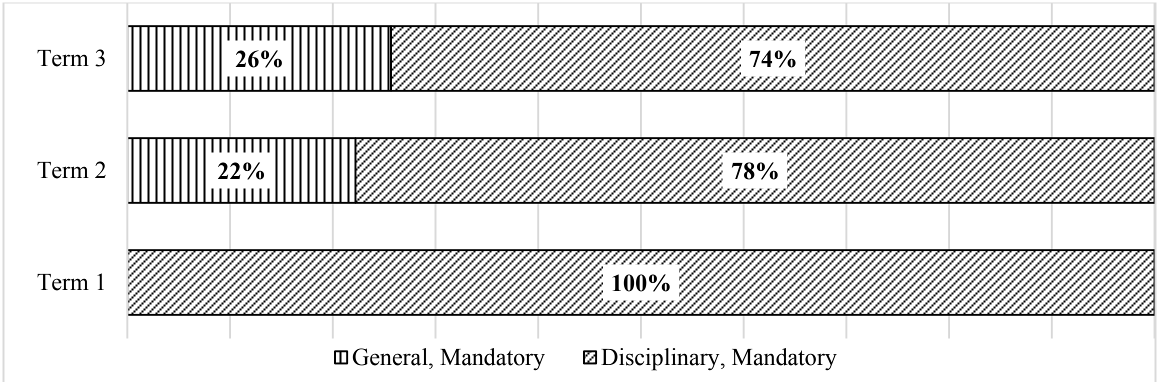

Figure 5.21 First-year Engineering Course Composition of 3-Term, University-Admitted Programs

5.1.3 Curriculum Composition by Matriculation Model and Accredited Program

At the third level of the analysis of curricula compositions, engineering programs were divided into two groups at first. The first group of programs was offered at institutions with multiple accredited programs. The second group of programs was offered at institutions with only one accredited program. Further, each group was divided into three subgroups by matriculation models. For each subgroup, results of engineering programs under different calendar systems are presented separately. Figure 5.22 shows the grouping of engineering programs at the third level of analysis.

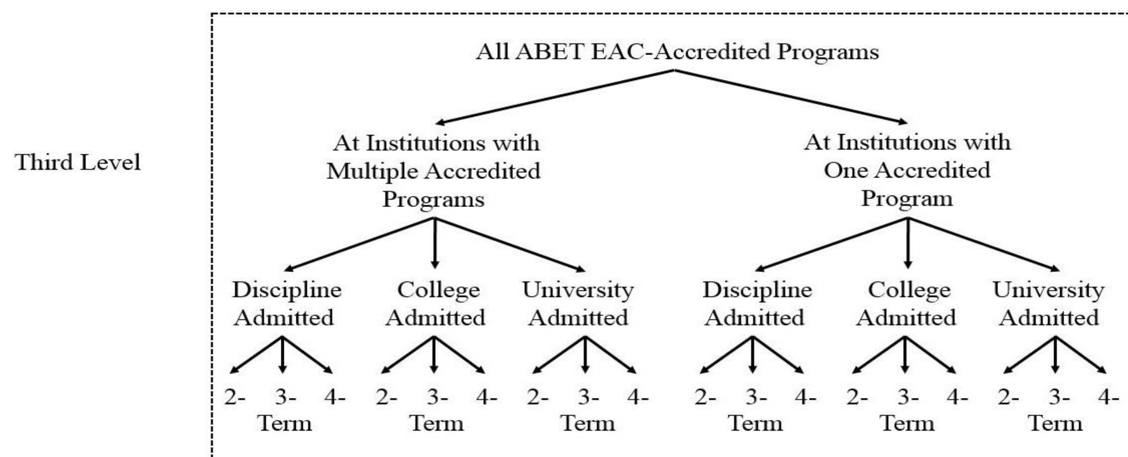

Figure 5.22 The Third Level of Analysis of the First-Year Curriculum Composition and Engineering Course Composition

Compositions at Institutions with Multiple Accredited Programs

As Table 5.1 shows, over 95% of the engineering programs were offered at institutions with more than one ABET EAC-accredited program. Therefore, the curricula compositions of engineering programs at institutions with multiple accredited programs were almost the same as the curricula compositions of all engineering programs. As a result, this study presents the curricula compositions of engineering programs at institutions with multiple accredited programs without further discussion (Figure 5.23 to Figure 5.32). Notably, all *College*-admitted engineering programs with 3-term course sequences belonged to institutions with multiple accredited programs. Their curricula compositions are already shown in Figure 5.14 and Figure 5.20. Similarly, all *Discipline*-admitted engineering programs with 4-term course sequences belonged to institutions with multiple accredited programs. Their course compositions are already shown in Figure 5.5 and Figure 5.8.

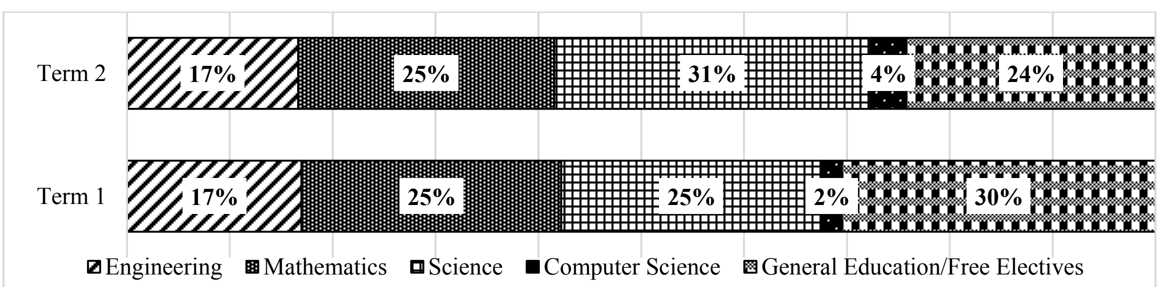

Figure 5.23 First-year Course Composition of 2-Term, Discipline-Admitted Programs at Institutions with Multiple Accredited Engineering Programs (Number of Institutions = 1,085)

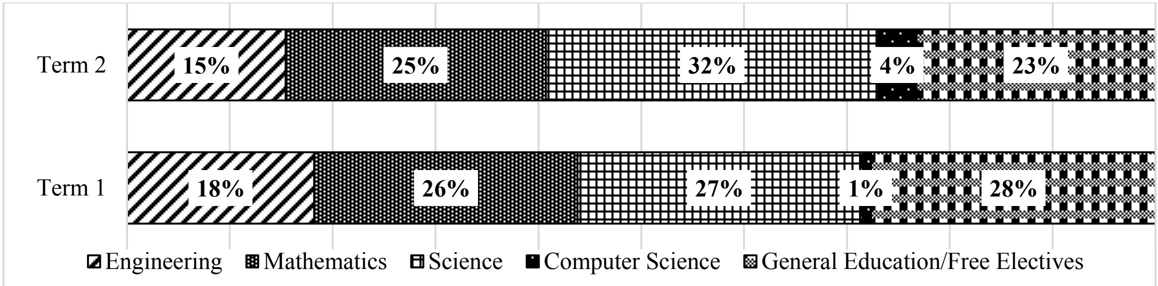

Figure 5.24 First-year Course Composition of 2-Term, College-Admitted Programs at Institutions with Multiple Accredited Engineering Programs (Number of Institutions = 415)

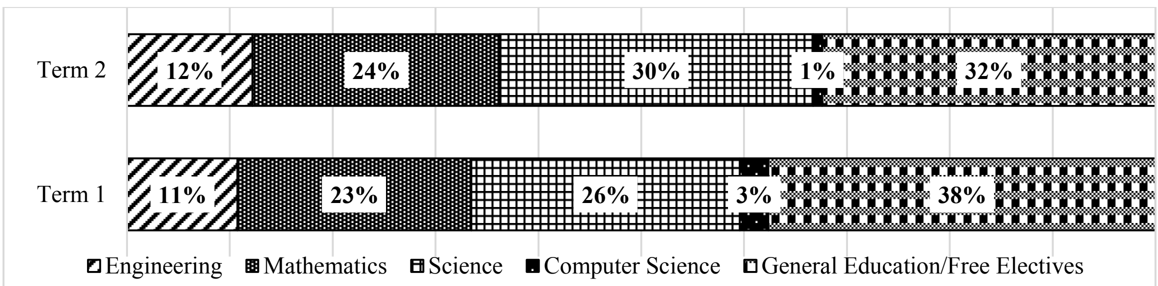

Figure 5.25 First-year Course Composition of 2-Term, University-Admitted Programs at Institutions with Multiple Accredited Engineering Programs (Number of Institutions = 86)

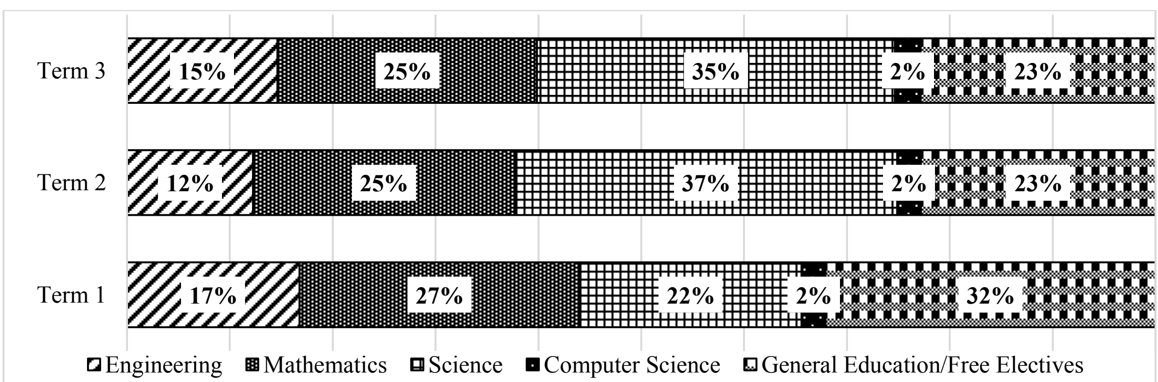

Figure 5.26 First-year Course Composition of 3-Term, Discipline-Admitted Programs at Institutions with Multiple Accredited Engineering Programs (Number of Institutions = 168)

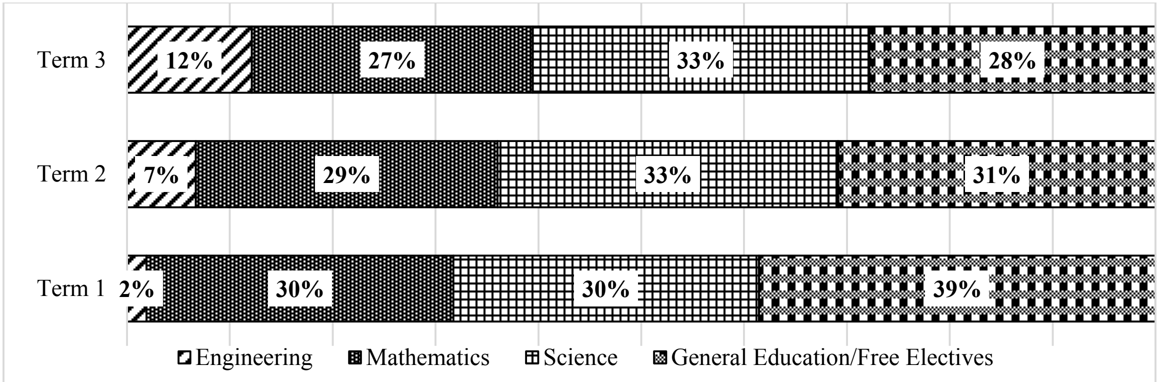

Figure 5.27 First-year Course Composition of 3-Term, University-Admitted Programs at Institutions with Multiple Accredited Engineering Programs (Number of Institutions = 18)

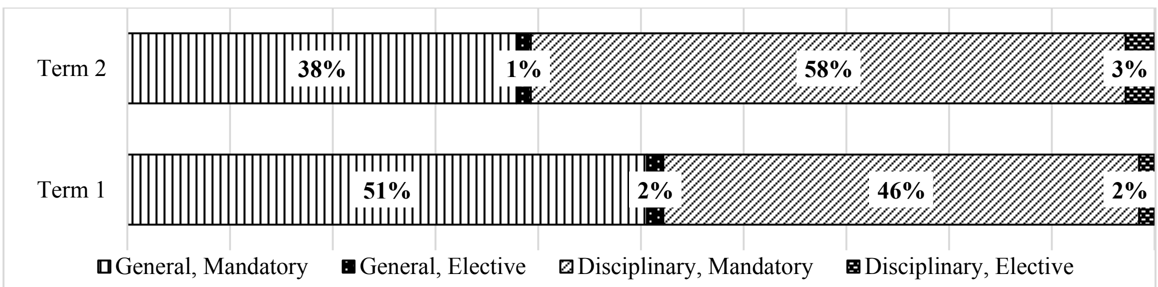

Figure 5.28 First-year Engineering Course Composition of 2-Term, Discipline-Admitted Programs at Institutions with Multiple Accredited Engineering Programs

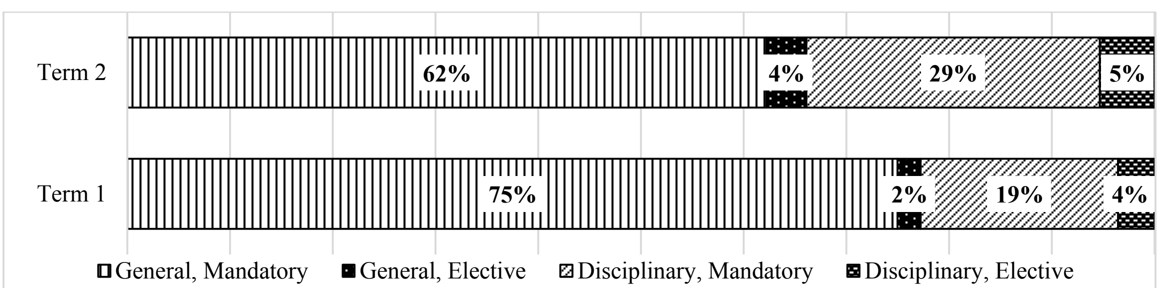

Figure 5.29 First-year Engineering Course Composition of 2-Term, College-Admitted Programs at Institutions with Multiple Accredited Engineering Programs

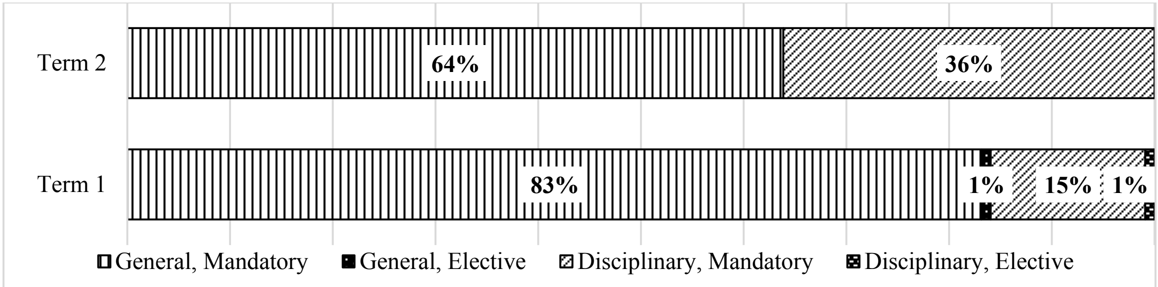

Figure 5.30 First-year Engineering Course Composition of 2-Term, University-Admitted Programs at Institutions with Multiple Accredited Engineering Programs

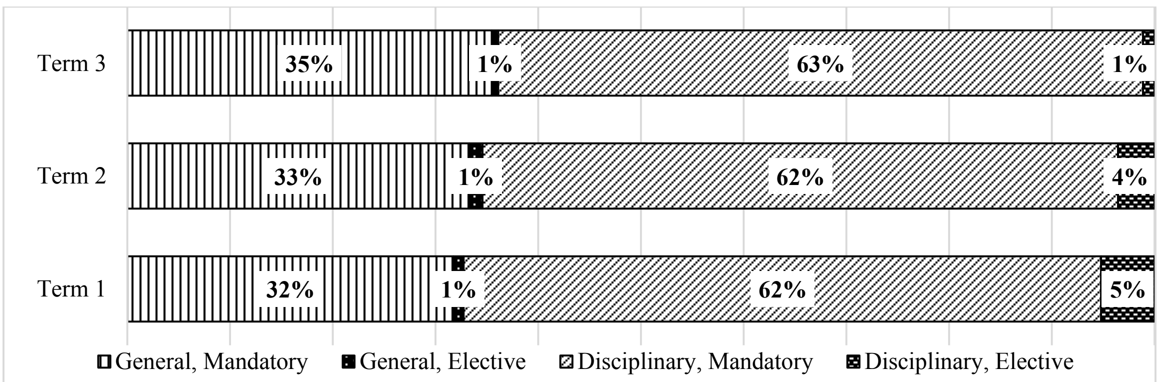

Figure 5.31 First-year Engineering Course Composition of 3-Term, Discipline-Admitted Programs at Institutions with Multiple Accredited Engineering Programs

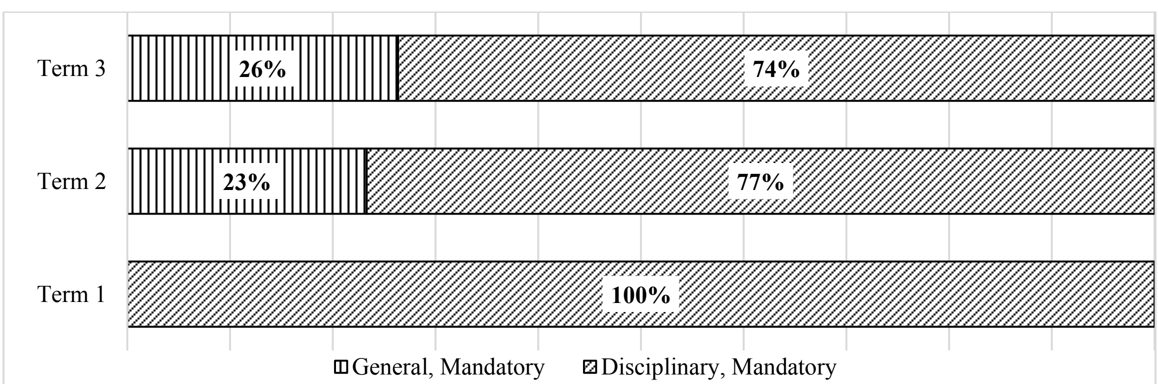

Figure 5.32 First-year Engineering Course Composition of 3-Term, University-Admitted Programs at Institutions with Multiple Accredited Engineering Programs

Compositions at Institutions with One Accredited Program

As Table 5.1 shows, 68 engineering programs were at institutions with one ABET EAC-accredited program with available curriculum data. In the sample, 63 programs offered 2-term course sequences, 5 programs offered 3-term course sequences, and 1 program offered 4-term course sequence. Figure 5.33, Figure 5.34, and Figure 5.35 present the first-year curricula compositions of programs with 2-term course sequences by matriculation models. Figure 5.36 and Figure 5.37 present the first-year curricula compositions of programs with 3-term course sequences at *Discipline-* and *University*-admitted institutions. For the compositions of first-year engineering courses, Figure 5.38, Figure 5.39, and Figure 5.40 present the results for programs offering 2-term course sequences. Figure 5.41 and Figure 5.42 present the engineering course compositions of *Discipline-* and *University*-admitted programs offering 3-term course sequences. Considering the sample size of each group, this study focuses discussion on the curriculum composition of 2-term engineering programs only. Curricula compositions of other groups of engineering programs are presented for completeness.

For the composition of first-year curriculum by five course categories, *Discipline*- and *College*-admitted programs at institutions with one accredited program offered lower percentages of mathematics and science courses and a higher percentage of general education/free elective courses than their counterparts at institutions with multiple accredited programs. Surprisingly, *University*-admitted programs at institutions with one accredited program offered a significantly lower percentage of general education/free elective courses than their counterparts at institutions with multiple accredited programs. Overall, engineering programs at institutions with one accredited program offered a higher percentage of engineering courses than engineering programs at institutions with multiple accredited programs. It may be indicative of a stronger desire of engineering programs at institutions with one accredited engineering program to help students create a sense of belonging by exposing students to the engineering field as much as possible.

For the composition of first-year engineering course, engineering programs at institutions with one accredited program offered a significantly higher percentage of general engineering courses than engineering programs at institutions with multiple accredited programs. It could be attributable to the fact that the only accredited program offered at an institution was more likely to be a general program instead of a disciplinary program. In this study, a "general engineering program" was referred to a program with the name "Engineering" shown on the ABET website (as opposed to "XXX Engineering" such as "Civil Engineering"). There were 45 programs with the name "Engineering" in 1,969 non-repeated ABET EAC-accredited programs. Only 13 (29%) of them were offered at institutions with multiple accredited programs. The other 32 (71%) programs were offered at institutions with one accredited program. Therefore, institutions with one accredited program were more likely to offer general engineering courses rather than disciplinary engineering courses in the first year.

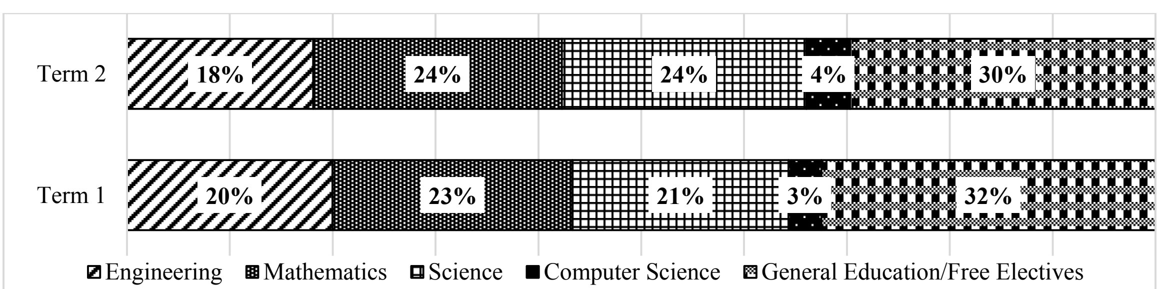

Figure 5.33 First-year Course Composition of 2-Term, Discipline-Admitted Programs at Institutions with One Accredited Engineering Program (Number of Institutions = 46)

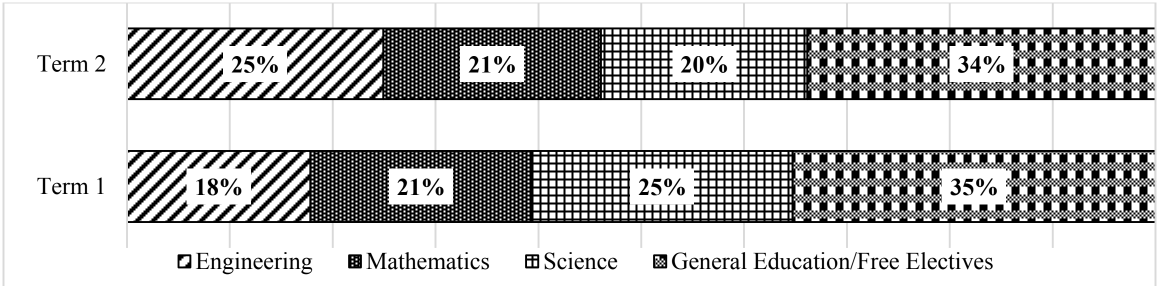

Figure 5.34 First-year Course Composition of 2-Term, College-Admitted Programs at Institutions with One Accredited Engineering Program (Number of Institutions = 5)

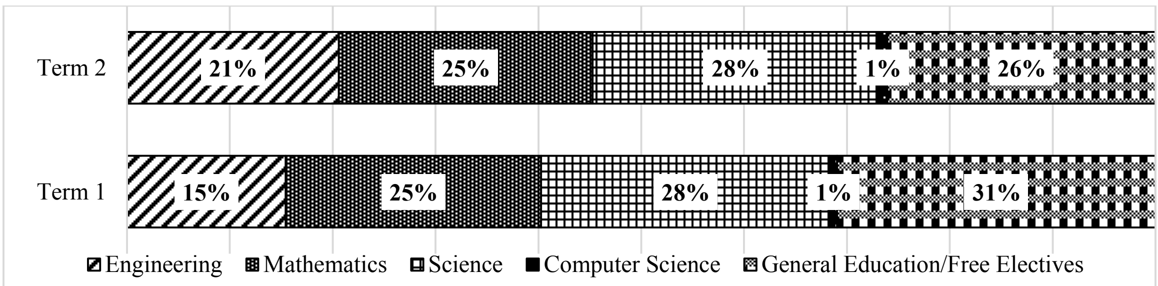

Figure 5.35 First-year Course Composition of 2-Term, University-Admitted Programs at Institutions with One Accredited Engineering Program (Number of Institutions = 12)

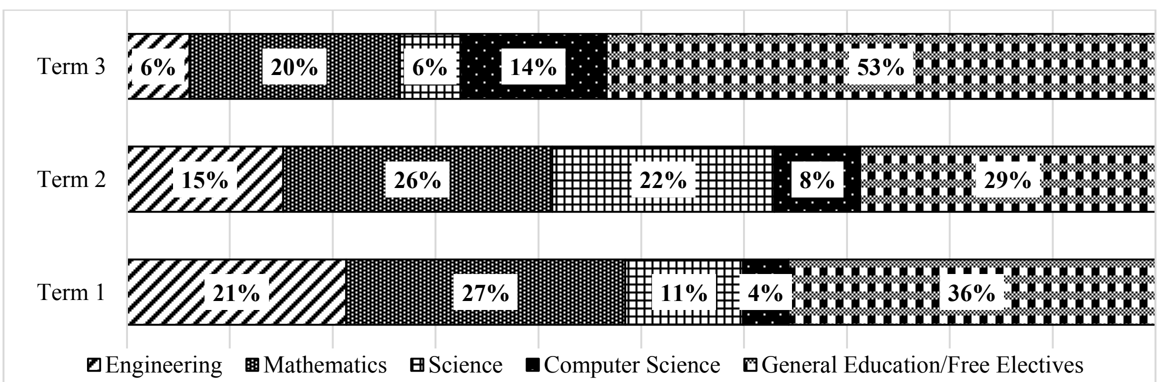

Figure 5.36 First-year Course Composition of 3-Term, Discipline-Admitted Programs at Institutions with One Accredited Engineering Program (Number of Institutions = 4)

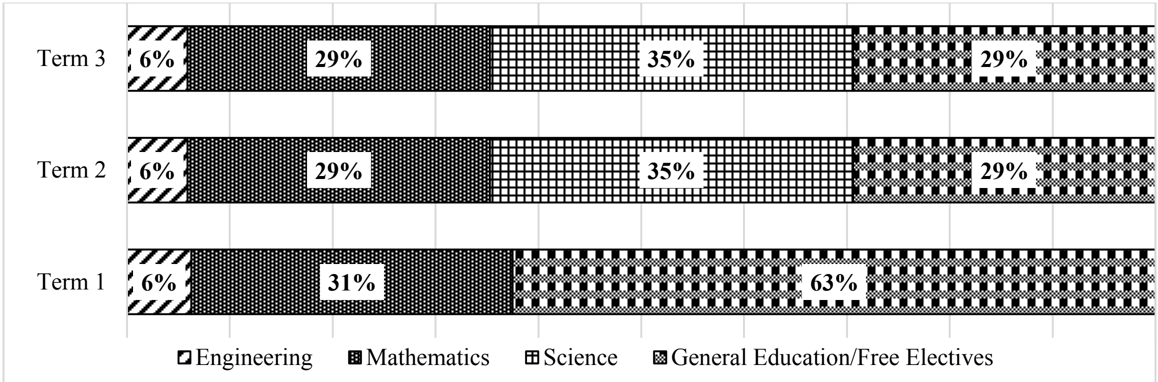

Figure 5.37 First-year Course Composition of 3-Term, University-Admitted Programs at Institutions with One Accredited Engineering Program (Number of Institution = 1)

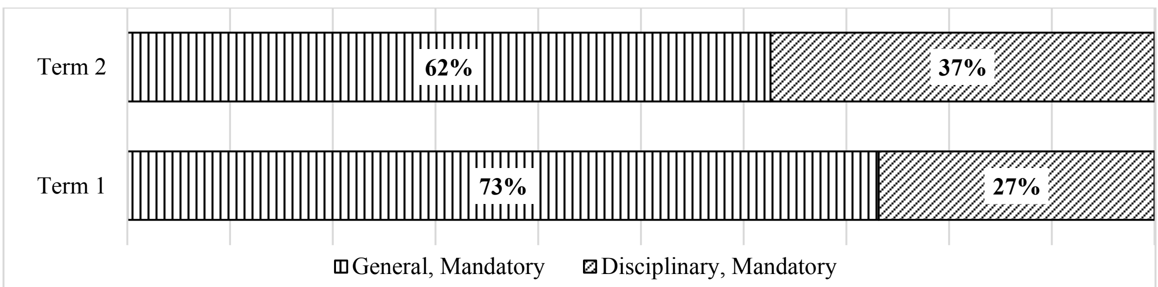

Figure 5.38 First-year Engineering Course Composition of 2-Term, Discipline-Admitted Programs at Institutions with One Accredited Engineering Program

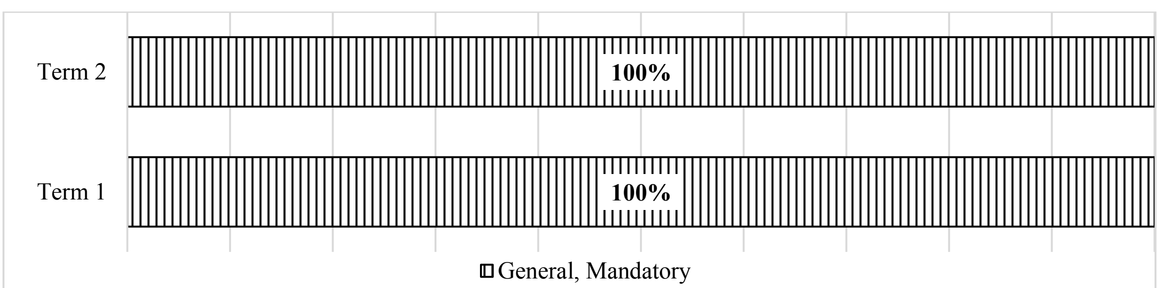

Figure 5.39 First-year Engineering Course Composition of 2-Term, College-Admitted Programs at Institutions with One Accredited Engineering Program

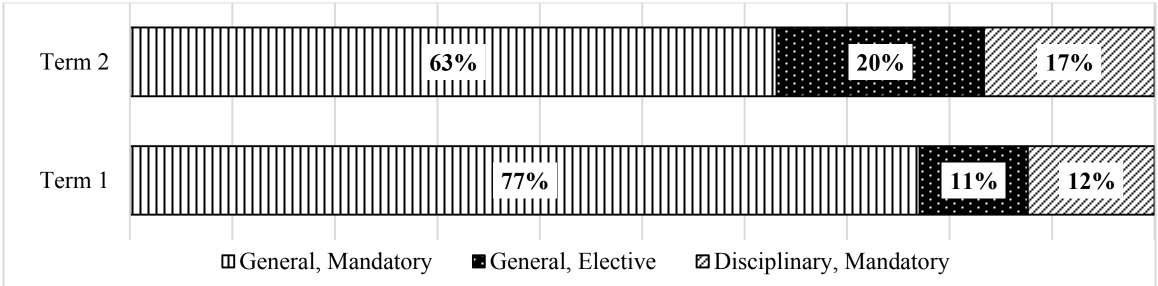

Figure 5.40 First-year Engineering Course Composition of 2-Term, University-Admitted Programs at Institutions with One Accredited Engineering Program

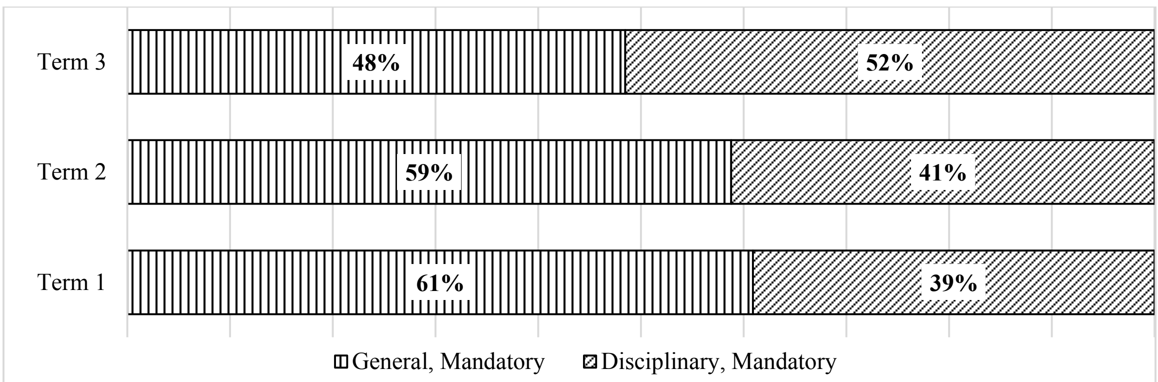

Figure 5.41 First-year Engineering Course Composition of 3-Term, Discipline-Admitted Programs at Institutions with One Accredited Engineering Program

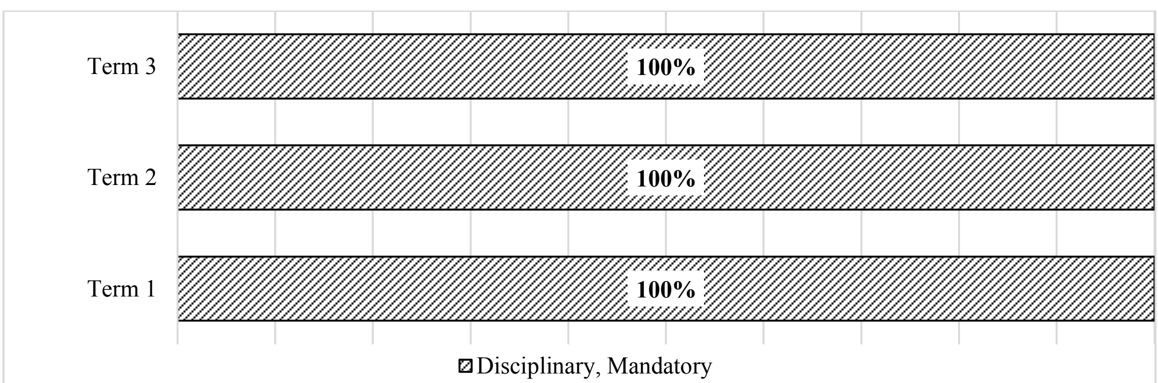

Figure 5.42 First-year Engineering Course Composition of 3-Term, University-Admitted Programs at Institutions with One Accredited Engineering Program

5.2 When the First Engineering Course Is Required

By examining the curriculum data, this study found that only 15 engineering courses offered by all ABET EAC-accredited programs were optional. The number of required (mandatory or elective) engineering courses was 4,803. Considering the predominance of required engineering courses in the first-year engineering curriculum, this study focused exclusively on the timing when the first engineering course and the first disciplinary engineering course were required.

The timing information of the first required engineering course and the first required disciplinary engineering course was recorded by Dimension 2 and Dimension 3 of the *Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses* (Table 3.1). Since all institutions with ABET EAC-accredited programs had already been classified using the taxonomy (Table 4.3), distributions of the first required engineering course and the first required disciplinary engineering course were drawn based on the institutions' classifications in the taxonomy. According to Table 4.3, 378 institutions were classified without missing data on any of the three dimensions of the taxonomy. The other 30 institutions were classified but information on at least one dimension was missing, as indicated by the question mark "?" in the place of the associated dimension in Table 4.3. Among 378 institutions with complete data on all dimensions of the taxonomy, 310 institutions had multiple accredited programs and 68 institutions had one accredited program. For institutions with multiple accredited programs, both the timing of the first required engineering course and the timing of the first required disciplinary engineering course were examined. Table 5.2 shows the result, and Figure 5.43 presents a visualization. For institutions with only one accredited engineering program, it doesn't make much sense to determine whether an engineering course is a general course or a disciplinary course from an engineering student's perspective. As such, only the timing of the first required engineering course was studied. Table 5.3 and a visualization in Figure 5.44 show when the first engineering course was required at institutions with one ABET EAC-accredited program.

Table 5.2 When the First Engineering Course and the First Disciplinary Engineering Course Are Required at Institutions with Multiple ABET EAC-Accredited Programs by Matriculation Models (Number of Institutions = 310)

	Time and Range of the Requirement	**Matriculation Model**		
		Discipline	**College**	**University**
Horizontal Comparison: First Required Engineering Course	Term 1, required by all programs	71.17%	76.47%	40.00%
	Term 1, required by some programs	26.13%	20.59%	20.00%
	Before term 2, required at least by some programs	97.30%	97.06%	60.00%
	Term 2, required at least by some programs	2.25%	1.47%	25.00%
	Before term 3, required at least by some programs	99.55%	98.53%	85.00%
	Term 3, required at least by some programs	0.45%	1.47%	5.00%
	Before term 4, required at least by some programs	100.00%	100.00%	90.00%
Vertical Comparison: First Required Disciplinary Engineering Course	Term 1, required by all programs	18.92%	8.82%	10.00%
	Term 1, required by some programs	46.40%	30.88%	15.00%
	Before term 2, required at least by some programs	65.32%	39.70%	25.00%
	Term 2, required at least by some programs	17.57%	19.12%	20.00%
	Before term 3, required at least by some programs	82.89%	58.82%	45.00%
	Term 3, required at least by some programs	13.96%	30.88%	35.00%
	Before term 4, required at least by some programs	96.85%	89.70%	80.00%
	Term 4, required at least by some programs	1.80%	5.88%	15.00%
	Before term 5, required at least by some programs	98.65%	95.58%	95.00%

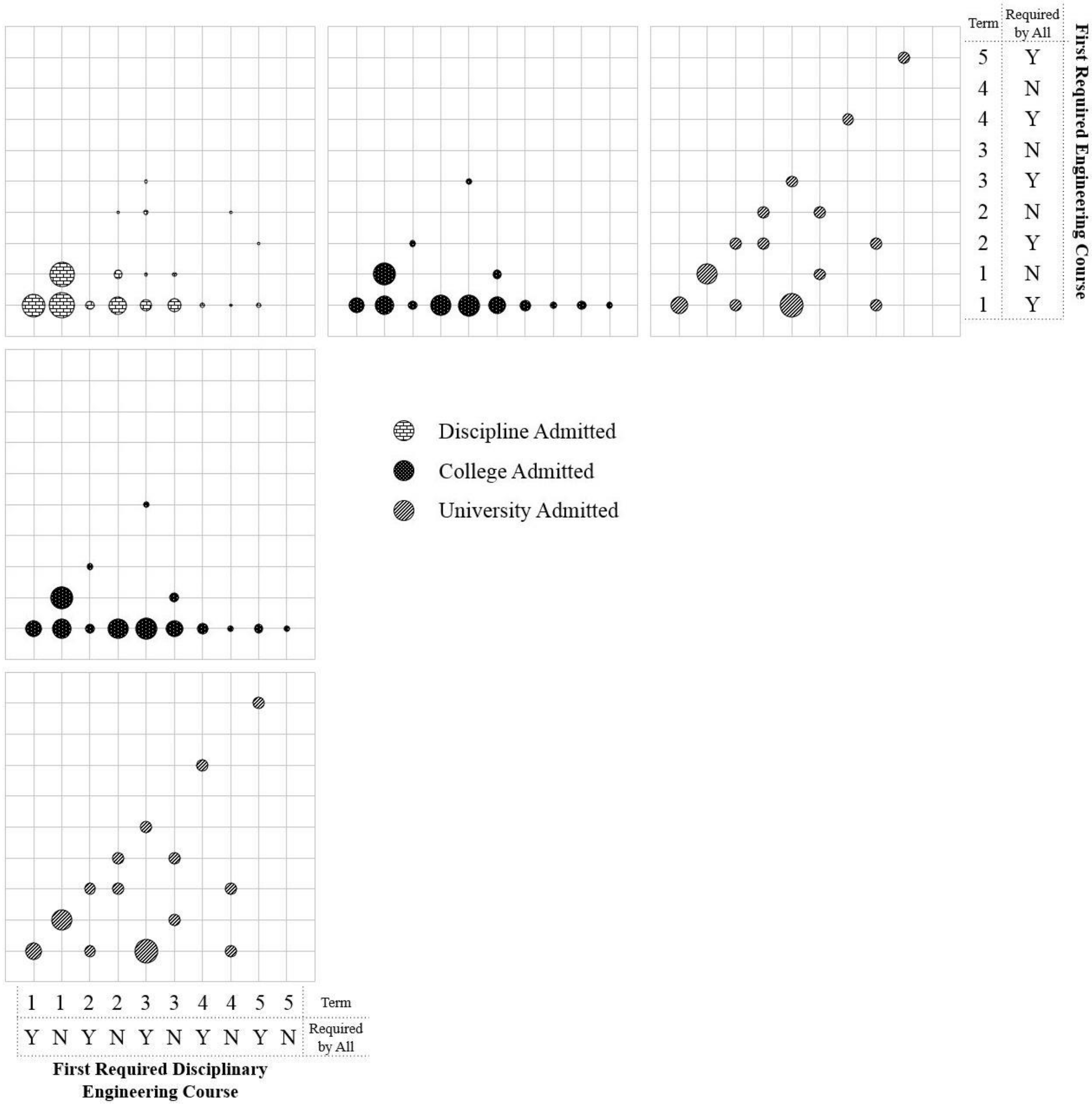

Figure 5.43 Distributions of the First Required Engineering Course and the First Required Disciplinary Engineering Course at Institutions with Multiple ABET EAC-Accredited Programs by Matriculation Models (Number of Institutions = 310)

Table 5.3 When the First Engineering Course Is Required at Institutions with One ABET EAC-Accredited Program by Matriculation Models (Number of Institutions = 68)

	Matriculation Model		
Required Term	**Discipline**	**College**	**University**
Term 1	94.00%	100.00%	69.23%
Term 2	6.00%	–	23.08%
Term 3	–	–	7.69%

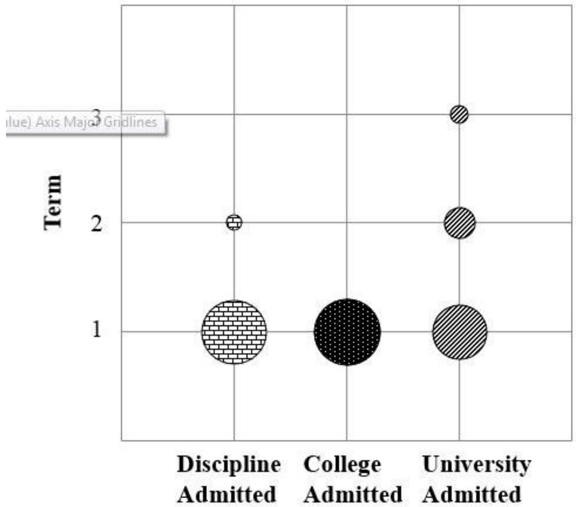

Figure 5.44 Distributions of the First Required Engineering Course at Institutions with One ABET EAC-Accredited Program by Matriculation Models (Number of Institutions = 68)

First, the distributions of the first engineering and disciplinary engineering courses required at institutions with multiple ABET EAC-accredited programs are discussed. Comparing the bubble charts horizontally in Figure 5.43, this study found that the majority of *Discipline*-admitted and *College*-admitted institutions required the first engineering course in the first term by all of their accredited engineering programs. Almost all of the *Discipline*-admitted and *College*-admitted institutions required the first engineering course in the first term at least by some of their accredited engineering programs. All *Discipline*-admitted and *College*-admitted institutions required the first engineering course no later than term 3. In comparison, *University*-admitted institutions had a more scattered pattern of the distribution of the first required engineering course. While looking at specific numbers in Table 5.2, the percentages of institutions requiring the first engineering course in term 1 by all accredited programs were 71% for *Discipline*-admitted institutions, 76% for *College*-admitted institutions, and only 40% for

University-admitted institutions. Over 97% of *Discipline*-admitted and *College*-admitted institutions required the first engineering course at least by some of their accredited programs in the first term. In comparison, the percentage was 60% for *University*-admitted institutions. After the third term, 10% of the *University*-admitted institutions still had not required any engineering course.

When comparing the bubble charts vertically in Figure 5.43, this study found that *Discipline*-admitted institutions were the most likely to require the first disciplinary engineering course at least by some accredited programs in term 1. The distributions of the first required disciplinary engineering course across terms were less concentrated for *College*-admitted and *University*-admitted institutions. As Table 5.2 shows, over 65% of the *Discipline*-admitted institutions require the first disciplinary engineering course in the first term at least by some accredited programs. The percentages were roughly 40% for *College*-admitted institutions and 25% for *University*-admitted institutions. By the third term, almost all *Discipline*-admitted institutions (97%) required the first disciplinary engineering course at least by some of their accredited programs. Near 90% of the *College*-admitted institutions and 80% of the *University*-admitted institutions did so.

Second, this study examines the distributions of the first required engineering course at institutions with one ABET EAC-accredited program. As Table 5.3 and Figure 5.44 show, all *College*-admitted institutions required the first engineering course in the first term. 94% of the *Discipline*-admitted institutions and nearly 70% of the *University*-admitted institutions did so. *Discipline*-admitted institutions required the first engineering course no later than term 2. *University*-admitted institutions required the first engineering course no later than term 3.

Overall, *Discipline*-admitted and *College*-admitted institutions required students to take the first engineering course earlier than *University*-admitted institutions. Almost all *Discipline*- and *College*-admitted institutions required the first engineering course at least by some of their accredited engineering programs early in the first term. Only 60% of *University*-admitted institutions did so. While the timetables of requiring the first engineering course were similar between *Discipline*-admitted and *College*-admitted institutions, the two types of institutions had apparently different schedules on the first disciplinary engineering course. *Discipline*-admitted institutions were prone to require the first disciplinary engineering course in the first term at lease by some accredited programs, whereas *College*-admitted institutions were more likely to postpone the first disciplinary engineering course until the third term (i.e. the first term in the second year for nearly 90% of the programs). Specifically, *Discipline*-admitted institutions were 25% more likely than *College*-admitted institutions to require the first disciplinary engineering course at least by some accredited programs in term 1. At the end of the second term, around 83% of *Discipline*-admitted institutions require the first disciplinary engineering course at least by some accredited programs. The percentages for *College*-admitted and *University*-admitted institutions were nearly 59% and 45% respectively.

This study finds remarkable agreements between the curriculum composition and the time when the first engineering course is required for engineering programs adopting the same matriculation model. Firstly, results of the first-year curriculum composition show that the percentage of engineering courses was significantly higher in *Discipline*- and *College*-admitted engineering programs than the percentage in *University*-admitted programs. Consistently, a much larger proportion of *Discipline*- and *College*-admitted institutions required the first engineering course at least by some programs in the first year, as compared with the proportion of *University*-admitted institutions. Secondly, *Discipline*-admitted programs required a significantly higher percentage of disciplinary engineering courses in the first year than *College*- and *University*-admitted programs. Correspondingly, *Discipline*-admitted institutions were much more likely than *College*- and *University*-admitted institutions to require the first disciplinary engineering course at least by some programs in the first year.

The time when the first engineering course is required is highly related to student outcomes. As Orr et al. (2013) pointed out, students required to take an introductory engineering course are more likely to stay in engineering than students not required to do so. By introducing students to the engineering discipline early in the first term, *Discipline*- and *College*-admitted institutions have a higher chance to retain students in engineering than *University*-admitted institutions, as noted by recent studies (Orr, et al., 2013; Orr, et al., 2012). The schedule of the first required engineering course may affect students' degree completion time as well. The work of Orr and her colleagues (2012) demonstrated that *University*-admitted students spent extra 1.67 terms than *Discipline*- and *College*- admitted students to graduate. Results of their study are not surprising because *University*-admitted institutions are far less likely to require the first engineering course in the first year than *Discipline*- and *College*-admitted institutions. Regarding the schedule of the first disciplinary engineering course, *Discipline*-admitted institutions may feel it more important to introduce disciplinary engineering courses early in the curriculum, as compared with *College*- and *University*-admitted institutions. As Bowman et al. (2003) pointed out, exposing students with designated major to discipline-specific engineering courses in the first term provides students with the opportunity to catch the excitement of their selected field. Information on the applicability of disciplinary engineering principles and availability of possible careers helps students make better-informed decisions regarding their educational plans and career paths. “Such information should be made available to students as early as possible – certainly to new students in the first semester of their freshman year.” (Bowman, et al., 2003, p. 24) With a different approach, *College*-admitted institutions deem the introduction of a general engineering course a better way to help students navigate their paths in engineering. General engineering courses provide students with a consistent grounding in fundamental engineering principles and skills, and make students aware of different options within engineering. For students entering *College*-admitted institutions who are “forced” to wait to declare a major, general engineering courses could be a better choice than disciplinary courses in helping them determine which major suits their personal interests and skills best.

5.3 First-year Engineering Course Keywords

As mentioned in Section **Error! Reference source not found.**, a total of 2,222 non-repeated first-year engineering courses were selected for the analysis of course descriptions. Keywords extracted from engineering courses were classified into categories using the revised *First-Year Engineering Course Classification Scheme* (**Error! Reference source not found.**). At the first stage of keyword analysis, this study calculated the average number of categories listed per course, and created the frequency list of topics. At the second stage of keyword analysis, categories extracted per course were grouped by institutions to get non-repeated categories at the institution level. This study calculated the average number of categories listed per institution, and calculated the average numbers for institutions with different matriculation models. Furthermore, this study created the frequency list of topics at the institution level, and compared the frequently listed categories of institutions with different matriculation models.

5.3.1 Keyword Analysis of Engineering Course

Using the revised *First-Year Engineering Course Classification Scheme* (**Error! Reference source not found.**), keywords extracted from 2,222 non-repeated first-year engineering courses were classified into 12,076 categories. These categories were non-repeated at the engineering course level. For instance, if more than one keyword extracted from the description of Course A was classified as *PROF III.0.0 Latent Curriculum/Professional Skills →Teamwork*, the category *PROF III.0.0* was counted only once for Course A.

At the first stage of keyword analysis, this study calculated the frequency of the number of categories listed per engineering course description, and created the frequency list of topics.

5.3.1.1 The Average Number of Categories Listed per Course

Figure 5.45 shows the frequency distribution of the number of categories listed per first-year engineering course description. Over 15% (342/2222) of the first-year engineering courses listed four different topics. Nearly 8% (173/2222) of the first-year engineering courses listed only one topic. Only six engineering courses listed twenty or more different topics. The average number of categories listed per first-year engineering course description was 5.4 (12076/2222). In other words, 5 to 6 different topics were included in the description of a first-year engineering course on average.

Since the average number of topics listed per course was calculated solely based on the course description, the above data should be interpreted with caution. A much larger number is expected if keywords are extracted from the course syllabus which provides more complete and detailed information on the coverage of course content.

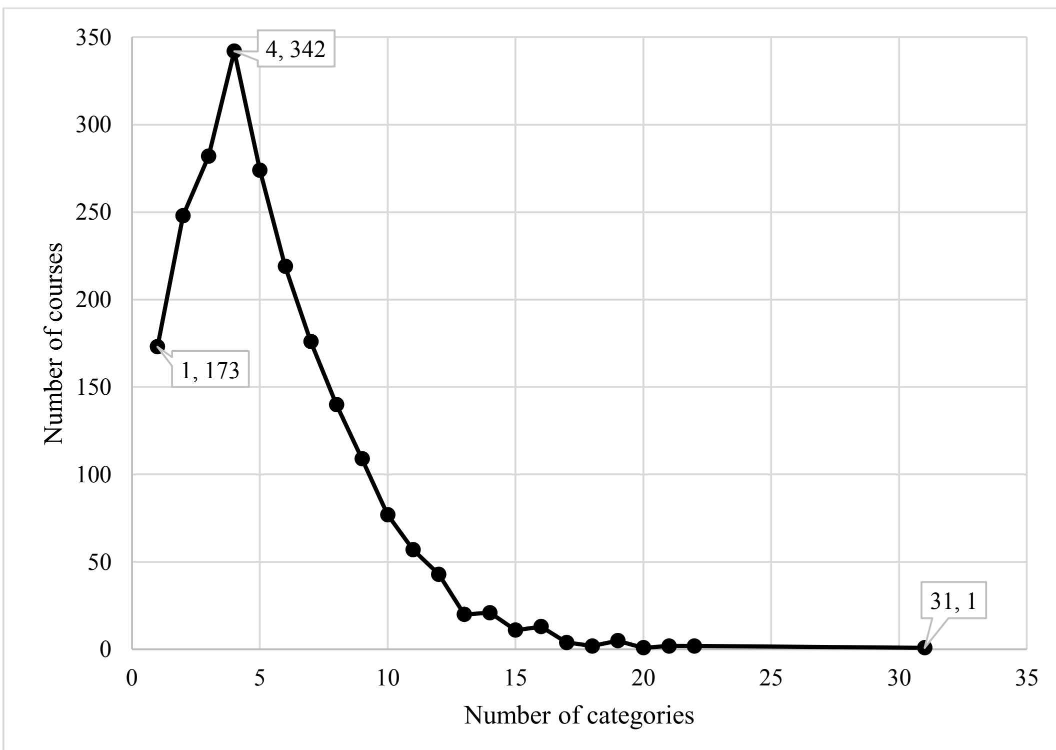

Figure 5.45 Frequency Distribution of the Number of Categories Listed per First-Year Engineering Course Description (Number of Courses = 2,222)

5.3.1.2 Frequencies of the Categories Listed in First-Year Engineering Course Descriptions

Based on the assumption that engineering programs include in the course description description those subjects which they consider to be critically important for students to comprehend, an analysis of keywords is essential to reveal the body of foundational knowledge in first-year engineering courses. In 12,076 categories, twenty most frequently listed categories, ten least frequently listed categories, and categories that were never included in the descriptions of first-year engineering courses are summarized in Table 5.4, Table 5.5, and

Table 5.6 respectively. A complete list of frequency occurrence of the categories is provided in **Error! Reference source not found.**. As Table 5.4 shows, six of the most frequently listed categories were under the main topic *Engineering Specific Tech/Tools*, including laboratory experiments, software tools, programming skills, Computer Aided Design (CAD), graphics, and circuits. Five categories were under the main topic *Design*, including problem solving skills, basic design concepts, design project assignments, engineering analysis, and formal design process. Four frequently listed categories were under the main topic *Engineering Profession*, including basic engineering concepts, disciplines of engineering, engineering careers, and roles and responsibilities of engineers. Three categories were under *Latent Curriculum/Professional Skills*, including problem solving skills (overlaps with DESN III.0.0), teamwork, and engineering ethics. The remaining three frequently listed categories belonged to three separate main topics *Communication*, *Math Skills and Applications*, and *Academic Advising*. Specific topics of these categories were writing skills, data approximation, and academic advising related issues.

Table 5.4 Twenty Most Frequently Listed Categories in First-Year Engineering Course Descriptions

ID	Main Topic →Topic →Sub-Topic →Specific Topic	Frequency
ENPR VI.0.0	Engineering Profession →Definition and Vocabulary	658 (29.6%)
ESTT III.B.4	Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	596 (26.8%)
ESTT II.0.0	Engineering Specific Tech/Tools →Software	552 (24.8%)
DESN III.0.0 (PROF I.A.0)	Design →Problem Solving (Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving)	508 (22.9%)
ENPR VII.0.0	Engineering Profession →Disciplines of Engineering	481 (21.6%)
ESTT II.A.0	Engineering Specific Tech/Tools →Software →Programming	433 (19.5%)
DESN I.0.0	Design →Engineering Design Process	401 (18.0%)
ESTT II.C.0	Engineering Specific Tech/Tools →Software →Computer Aided Design	399 (18.0%)
ENPR VII.A.0	Engineering Profession →Disciplines of Engineering →Introduction to Professions	371 (16.7%)
DESN I.F.2	Design →Engineering Design Process →Authentic Design →Design Projects	366 (16.5%)
ESTT I.E.0	Engineering Specific Tech/Tools →Engineering Skills →Graphics	340 (15.3%)
PROF III.0.0	Latent Curriculum/Professional Skills →Teamwork	328 (14.8%)
DESN II.0.0	Design →Engineering Analysis	305 (13.7%)
PROF II.0.0	Latent Curriculum/Professional Skills →Ethics	298 (13.4%)
COMM II.0.0	Communication →Written	225 (10.1%)
ESTT I.B.0	Engineering Specific Tech/Tools →Engineering Skills →Circuits	196 (8.8%)
DESN I.A.3	Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	195 (8.8%)
MATH IX.C.0	Math Skills and Applications →Calculations →Estimation	166 (7.5%)
ACAD V.0.0	Academic Advising →Advising	165 (7.4%)
ENPR II.A.0	Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	154 (6.9%)

Among ten least frequently listed categories (Table 5.5), three categories were under the main topic *Academic Advising*, including stress management, academic integrity, and interview skills. Two categories were under the main topic *Communication*, including the creation of a research poster and having professional meetings with project sponsors. The remaining categories included brainstorming in a problem-solving activity, an entrepreneurial mindset to impact society as an engineer, empirical functions, software Arena, and conducting qualitative research.

Table 5.5 Ten Least Frequently Listed Categories in First-Year Engineering Course Descriptions

ID	Main Topic →Topic →Sub-Topic →Specific Topic	Frequency
ACAD II.B.0	Academic Advising →Personal Management →Stress Management	2 (0.1%)
ACAD IV.0.0	Academic Advising →Academic Integrity	2 (0.1%)
ACAD V.C.1	Academic Advising →Advising →Co-op or Internship →Interviews	2 (0.1%)
COMM IV.A.0	Communication →Visual →Posters	2 (0.1%)
DESN I.A.4	Design →Engineering Design Process →Fundamentals of Design →Brainstorming	2 (0.1%)
GLIN II.B.0	Global Interest →Concern for Society →Social Entrepreneurship	2 (0.1%)
MATH IX.A.1	Math Skills and Applications →Calculations →Statistics →Empirical Functions	2 (0.1%)
COMM I.A.0	Communication →Professional →Client Interactions	1 (<0.1%)
ESTT II.C.5	Engineering Specific Tech/Tools →Software →Computer Aided Design →Arena	1 (<0.1%)
PROF IV.B.0	Latent Curriculum/Professional Skills →Research →Qualitative	1 (<0.1%)

Table 5.6 Categories Never Listed in First-Year Engineering Course Descriptions

ID	Main Topic →Topic →Sub-Topic →Specific Topic
COMM I.0.0	Communication →Professional
DESN V.C.0	Design →Project Management →Verification
ESTT I.0.0	Engineering Specific Tech/Tools →Engineering Skills
ESTT II.B.0	Engineering Specific Tech/Tools →Software →Programming and Design
ESTT II.C.4	Engineering Specific Tech/Tools →Software →Computer Aided Design →Catia
ESTT III.A.3	Engineering Specific Tech/Tools →Hardware →Shop Experience →3-D Printing
ESTT III.B.0	Engineering Specific Tech/Tools →Hardware →Topic Specific Tools
ESTT III.B.5	Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Nanosensors
GLIN V.0.0	Global Interest →Virtual Reality
PROF III.A.1	Latent Curriculum/Professional Skills →Teamwork →Team Management →Work Distribution
PROF III.A.2	Latent Curriculum/Professional Skills →Teamwork →Team Management →Strength/Weakness ID

As

Table 5.6 shows, eleven categories were not listed in the descriptions of 2,222 first-year engineering courses. For some categories, their associated keywords never appeared in the course descriptions. For others, their keywords appeared but were classified by higher levels of topics in the classification scheme. For example, *Catia* and

Nanosensors were not found in any keyword extracted from first-year engineering course descriptions. *ESTT I.0.0 Engineering Specific Tech/Tools →Engineering skills* was one of the categories that were not listed. Keywords related to engineering skills were listed in the descriptions of a large number of courses, but they were all classified by a higher level of topic in this study. For instance, keyword “circuits” belonged to *Engineering skills*, but it was also under a more specific category *ESTT I.B.0 Engineering Specific Tech/Tools →Engineering Skills →Circuits*. Therefore it was classified as *ESTT I.B.0* instead of *ESTT I.0.0*, making *ESTT I.0.0* a category that was not included in the course description. A revision of the structure or redefinition of the classification scheme may solve this issue.

Further, this study took a closer look at the frequencies of categories that were listed in engineering course descriptions grouped by main topics. For each main topic, Table 5.7 summarizes the categories that were listed in the descriptions of at least 5% of the first-year engineering courses. Similar to Table 5.4, Table 5.7 provides hints about the priority of main topics in the first-year engineering courses. Still, the main topic *Engineering Specific Tech/Tools* included the largest number of categories appearing frequently in first-year engineering course descriptions, followed by *Design* and *Engineering Profession*. Categories under main topics *Academic Advising* and *Math Skills and Applications* were listed less frequently in first-year engineering course descriptions, but they were often included in the contents of courses belonging to other categories. For example, advising information such as helping students adjust to the new environment and introducing students to the university resources were usually given in the form of seminar or orientation that belonged to the general education/free elective course category instead of the engineering course category. Topics related to mathematics were covered mainly by courses belonging to the mathematics course category. Notably, none of the categories under *Global Interest* were listed in the descriptions of at least 5% of the first-year engineering courses, indicating little attention was given to the grand challenges for engineering proposed by NAE (2014).

Table 5.7 Categories Listed in at Least Five Percent of the Descriptions of the First-Year Engineering Courses

ID		Main Topic →Topic →Sub-Topic →Specific Topic	Frequency
ACAD	V.0.0	Academic Advising →Advising	165 (7.4%)
	V.E.0	Academic Advising →Advising →Introduction to Departments	128 (5.8%)
COMM	II.0.0	Communication →Written	225 (10.1%)
	III.0.0	Communication →Oral and Visual	140 (6.3%)
	III.A.0	Communication →Oral and Visual →Presentations	111 (5.0%)
DESN	III.0.0	Design →Problem Solving	508 (22.9%)
	I.0.0	Design →Engineering Design Process	401 (18.0%)
	I.F.2	Design →Engineering Design Process →Authentic Design →Design Projects	366 (16.5%)
	II.0.0	Design →Engineering Analysis	305 (13.7%)
	I.A.3	Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	195 (8.8%)
ENPR	VI.0.0	Engineering Profession →Definition and Vocabulary	658 (29.6%)
	VII.0.0	Engineering Profession →Disciplines of Engineering	481 (21.6%)
	VII.A.0	Engineering Profession →Disciplines of Engineering →Introduction to Professions	371 (16.7%)
	II.A.0	Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	154 (6.9%)
	I.0.0	Engineering Profession →Relevance of the Profession	122 (5.5%)
ESTT	III.B.4	Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	596 (26.8%)
	II.0.0	Engineering Specific Tech/Tools →Software	552 (24.8%)
	II.A.0	Engineering Specific Tech/Tools →Software →Programming	433 (19.5%)
	II.C.0	Engineering Specific Tech/Tools →Software →Computer Aided Design	399 (18.0%)
	I.E.0	Engineering Specific Tech/Tools →Engineering Skills →Graphics	340 (15.3%)
	I.B.0	Engineering Specific Tech/Tools →Engineering Skills →Circuits	196 (8.8%)
	I.E.2	Engineering Specific Tech/Tools →Engineering Skills →Graphics →Sketching	135 (6.1%)
	II.D.2	Engineering Specific Tech/Tools →Software →Microsoft Office →Excel	130 (5.9%)
GLIN		NONE	
MATH	IX.C.0	Math Skills and Applications →Calculations →Estimation	166 (7.5%)
PROF	I.A.0	Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving	508 (22.9%)
	III.0.0	Latent Curriculum/Professional Skills →Teamwork	328 (14.8%)

II.0.0	Latent Curriculum/Professional Skills →Ethics	298 (13.4%)

According to a study done by Lattuca and her colleagues (2006), the engineering curriculum had increased emphasis on professional skills and knowledge to accommodate the ABET EC2000 Criterion 3. Conclusions of their study were made based on feedback from nearly 1,400 faculty members and program chairs. Using course content analysis as an alternative approach, this study confirms that many of the frequently listed topics in first-year engineering courses map onto the student outcomes listed in ABET EC2000 Criterion 3 (ABET, 2013a). Specifically, frequently listed topics that map onto criterion 3 include: (1) conducting experiments; (2) data analysis; (3) design process and design related concepts; (4) teamwork; (5) problem solving skills; (6) ethics; (7) contemporary issues; and (8) usage of engineering technologies and tools. Nevertheless, the complete frequency list (**Error! Reference source not found.**) suggests that there is little to no instructional emphasis in the first year curriculum on the following aspects of knowledge and skills associated with Criterion 3: (1) design criteria and constraints; (2) communicate effectively in realistic settings; (3) awareness of the impact of engineering solutions in a global context; and (4) life-long learning. While Lattuca et al.'s study (2006) revealed changes in the engineering curriculum after the implementation of the ABET EC2000 criteria, this research provides a snapshot of how the first-year engineering curriculum connects with EC2000 Criterion 3 in particular.

Another comparison is made between the frequency list of categories and the twenty skills and knowledge items listed in *The Final Report for the Center for the Advancement of Engineering Education* (Atman, et al., 2010) (Figure 5.46). Items of the list were drawn from the ABET Criterion 3 outcomes (ABET, 2013a) and *The Engineer of 2020* (National Academy of Engineering, 2004) – the phase one report completed by NAE. The researchers of CAEE provided the items in a survey for senior engineering students to select the most important engineering skills and knowledge. Figure 5.46 shows the twenty items and their ratings based on the survey (the most important item was listed on the top). This study finds a positive relationship between the frequency of a topic listed in the course descriptions and the importance of the topic measured by the rating of senior engineering students. The five most frequently cited important items, as indicated by the top five bars in Figure 5.46, appeared frequently in the descriptions of first-year engineering courses. Problem solving was listed in the descriptions of 23% of the first-year engineering courses. Three specific topics under the main topic *Communication* were listed by at least 5% of the first-year engineering courses. Teamwork, engineering analysis, and ethics were all listed by at least 13% of the first-year engineering courses. Meanwhile, seven relatively less selected items were insufficiently mentioned in the descriptions of first-year engineering courses, including: (1) creativity; (2) life-long learning; (3) leadership; (4) business knowledge; (5) management skills; (6) global context; and (7) societal context. While students' perception of important items may be affected by what they learned in later years, it is possible that first-year engineering course content selection has a long-term influence on students' recognition of critical engineering knowledge and skills. As CAEE pointed out, first-year engineering students may interpret the concepts introduced in an introductory engineering course as indications that these concepts are important in engineering (Atman, et al., 2010).

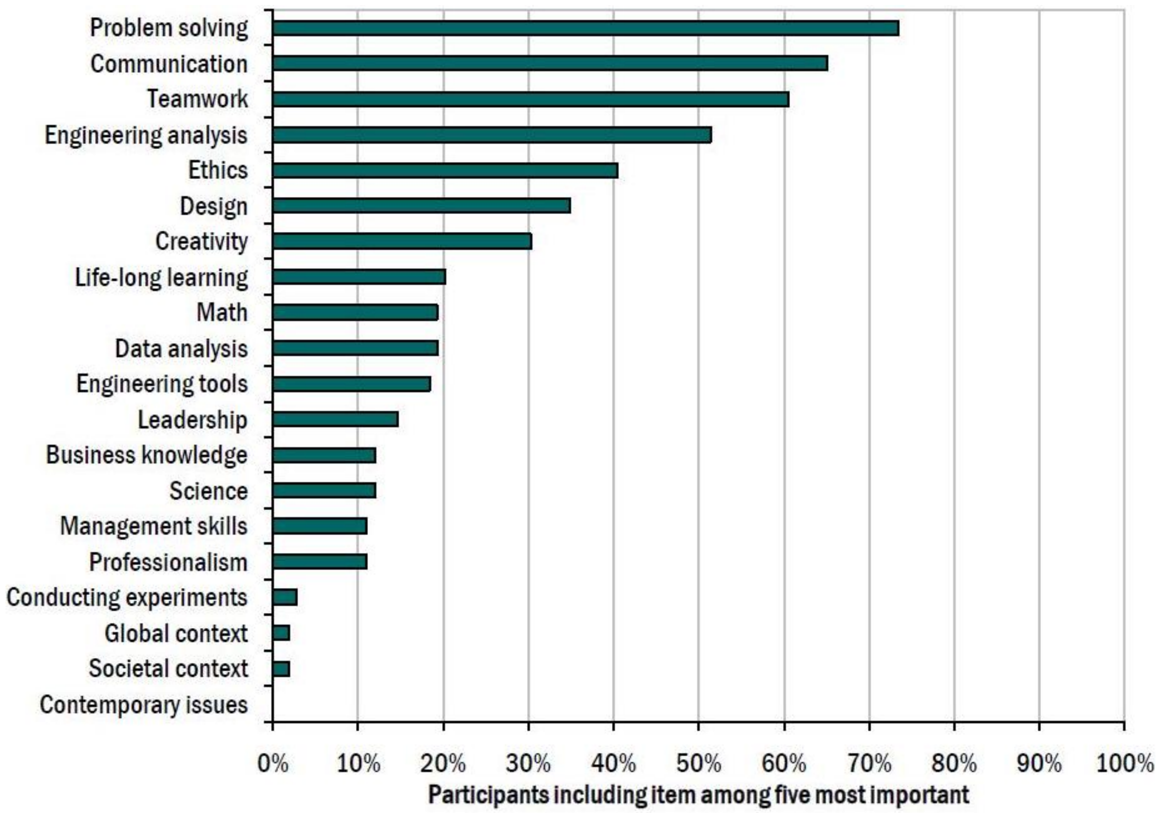

Figure 5.46 Engineering Skills and Knowledge Items and the Percentage of Longitudinal Cohort Seniors Who Selected Each among Their Set of Five Most Important Items
Note. From "Enabling Engineering Student Success: The Final Report for the Center for the Advancement of Engineering Education," by C. J. Atman, S. D. Sheppard, J. Turns, R. S. Adams, L. N. Fleming, R. Stevens., . . . D. Lund, 2010, p. 51, San Rafael, CA: Morgan & Claypool Publishers. Copyright 2010 by Morgan & Claypool Publishers. Reprinted with permission.

5.3.2 Keyword Analysis by Institution and by Matriculation Model

Among 408 institutions with ABET EAC-accredited programs, 374 institutions were selected for the analysis of first-year engineering course keywords. The remaining 34 institutions were excluded because they either did not list any engineering course in their first-year suggested course sequences or did not provide descriptions for first-year engineering courses online. Categories extracted per course were grouped by institutions to get non-repeated categories at the institution level. For example, if more than one first-year engineering course mentioned *PROF III.0.0 Teamwork* at Institution A, the category *PROF III.0.0* was counted only once for Institution A. Accordingly, the number of non-repeated categories at the institution level was 7,975.

At the second stage of keyword analysis, this study calculated the average number of categories listed per institution, and calculated the average numbers for institutions with different matriculation models. Further, this study created the frequency list of topics at the institution level, and compared the frequently listed categories of institutions with different matriculation models.

5.3.2.1 The Average Number of Categories Listed per Institution and per Matriculation Model

The frequency distribution of the number of categories listed per institution is shown in Figure 5.47. At nearly 6% of the institutions, all engineering courses offered in the first year listed a total of 13 different topics. The average number of categories included in the descriptions of first-year engineering courses per institution was 21.3 (7975/374). In other words, on average there were 21 to 22 different topics listed in the descriptions of first-year engineering courses per institution. Again, the above results should be interpret with caution because the numbers were calculated solely based on keywords extracted from course descriptions, which might differ greatly from what was taught in class.

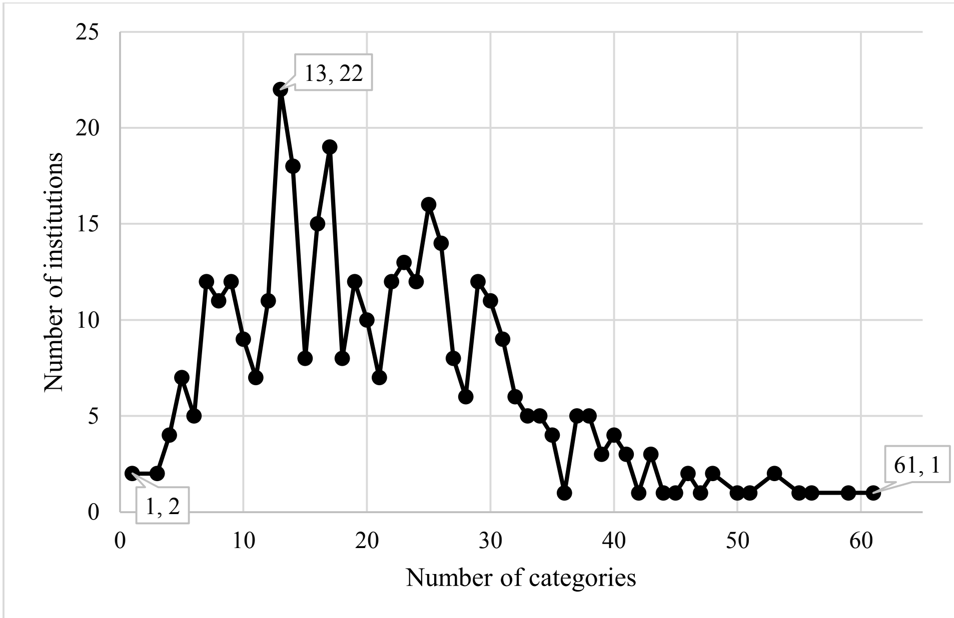

Figure 5.47 Frequency Distribution of the Number of Categories Listed per Institution (Number of Institutions = 374)

When 374 institutions were grouped by matriculation models, there were 270 (72%) *Discipline*-admitted institutions, 72 (19%) *College*-admitted institutions, and 30 (8%) *University*-admitted institutions. The remaining two institutions were undetermined due to insufficient online information. The average numbers of categories listed in first-year engineering course descriptions per *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions were 22.2, 21.4, and 14.1 respectively. The result was consistent with the findings of curricula compositions and the timing when the first engineering course was required. *University*-admitted institutions offered a significantly lower percentage of engineering courses in the first year and were more likely to postpone the first required engineering course than *Discipline*- and *College*-admitted institutions. Therefore, it is not surprising to see that *University*-admitted institutions had many fewer topics listed in the descriptions of first-year engineering courses.

When the number of accredited engineering program was considered along with the matriculation model, this study observed that institutions with multiple accredited programs listed more topics than institutions with only one accredited program, regardless which type of matriculation model they adopted. Specifically, the average numbers of categories listed in course descriptions by *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions with multiple accredited engineering programs were 24.3, 21.9, and 14.4 respectively. In comparison, the average numbers of categories listed in course descriptions by *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions with only one accredited engineering program were 12.7, 14.4, and 13.5 respectively. Course descriptions of *Discipline*-admitted institutions included almost twice as many topics if they had multiple accredited engineering programs than if they had only one program. The difference was still significant for *College*-admitted institutions. *College*-admitted institutions with multiple accredited programs listed 50% more topics than institutions with only one accredited program. Surprisingly, for *University*-admitted institutions, those with multiple programs listed only one more topic than institutions with one accredited program. Generally speaking, the more accredited engineering programs an institution has, the more engineering courses it offers in the first year, and therefore the more topics are included in the engineering course descriptions. It is especially true for *Discipline*-admitted institutions where students begin to take different disciplinary engineering courses early in the first year instead of taking universal general engineering courses. For *University*-admitted institutions, a pretty small gap between institutions with one program and institutions with multiple programs may be attributable to a much higher percentage of credit hours devoted to first-year engineering courses at institutions with one accredited program (Figure 5.35) than at institutions with multiple accredited programs (Figure 5.25), increasing the likelihood of including more topics at institutions with one accredited program.

5.3.2.2 The Average Number of Categories Listed per Institution and per Matriculation Model

A complete list of frequency occurrence of the categories at the institution level is provided in **Error! Reference source not found.**. The twenty most frequently listed categories at the institution level (**Error! Reference source not found.**) and the twenty most frequently listed categories at the engineering course level (Table 5.4) were almost identical except one category. Similarly, the ten least frequently listed categories were identical at the institution level (**Error! Reference source not found.**) and at the engineering course level (Table 5.5).

While taking a closer look at the categories listed by institutions with different matriculation models, this study finds that *Discipline*-admitted institutions, *College*-admitted institutions, and *University*-admitted institutions shared the majority of frequently listed categories. As Figure 5.48 shows, institutions with three different types of matriculation models shared seven out of ten most frequently listed topics. Additionally, *University*-admitted institutions shared one frequently listed topic with *Discipline*-admitted institutions, and shared the remaining two topics with *College*-admitted institutions.

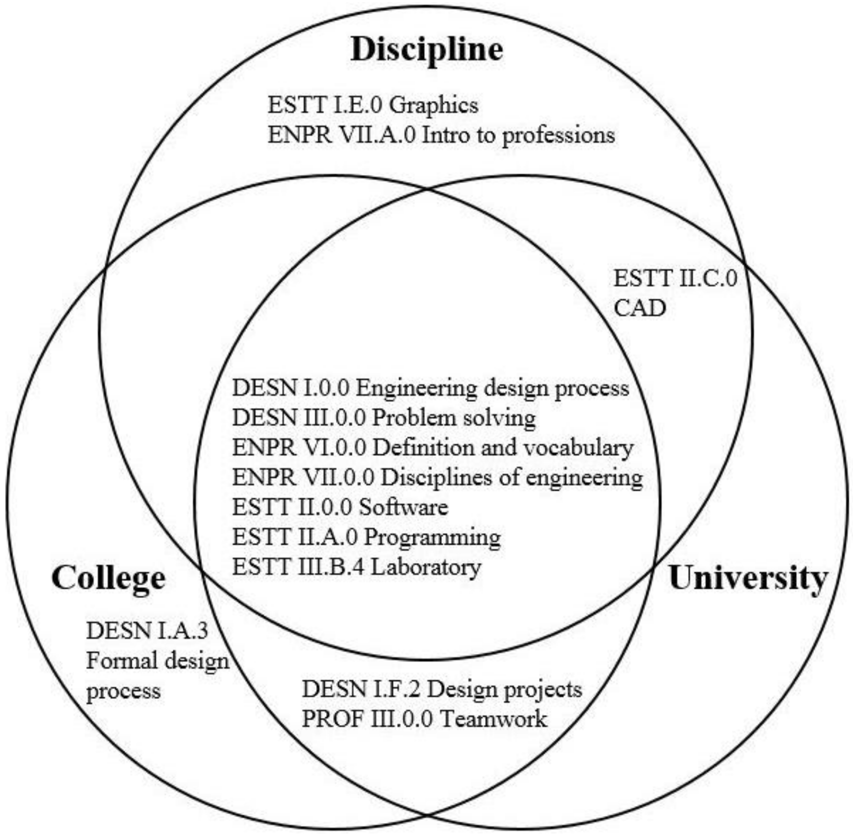

Figure 5.48 Overlaps of the Ten Most Frequently Listed Categories at Discipline-Admitted, College-Admitted, and University-Admitted Institutions

Figure 5.49 describes the overlaps of the top ten frequently listed categories among *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions with multiple accredited programs. The ten most frequently listed categories almost stayed the same when the sample institutions shrank from all institutions to institutions with multiple accredited programs. The top ten frequently listed categories were identical between *Discipline*-admitted institutions with multiple accredited programs and total *Discipline*-admitted institutions, so did *College*-admitted institutions. Only one of the top ten categories changed at *University*-admitted institutions. *ESTT II.C.0 CAD* was in the top ten list at *University*-admitted institutions. It was replaced by *ENPR VII.A.0 Introduction to Profession* for institutions with multiple accredited engineering programs.

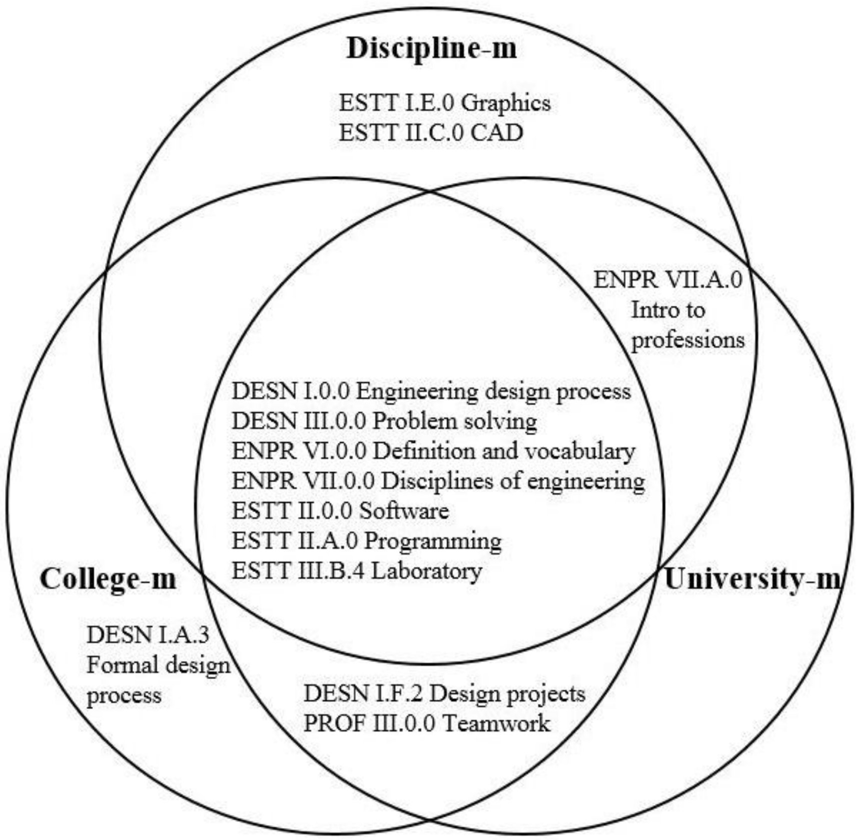

Figure 5.49 Overlaps of the Ten Most Frequently Listed Categories at Discipline-Admitted, College-Admitted, and University-Admitted Institutions with Multiple Accredited Engineering Programs

When institutions with only one accredited engineering program are considered, institutions with different matriculation models still shared seven out of ten most frequently appearing topics (Figure 5.50). However, a comparison between Figure 5.48 and Figure 5.50 shows that the top ten categories of institutions with one accredited programs were quite different from the top ten categories of all institutions. For example, *Disciplines of Engineering* was a shared categories by *Discipline*-admitted, *College*-

admitted, and *University*-admitted institutions, but it was not included in any top ten list of institutions with only one accredited program.

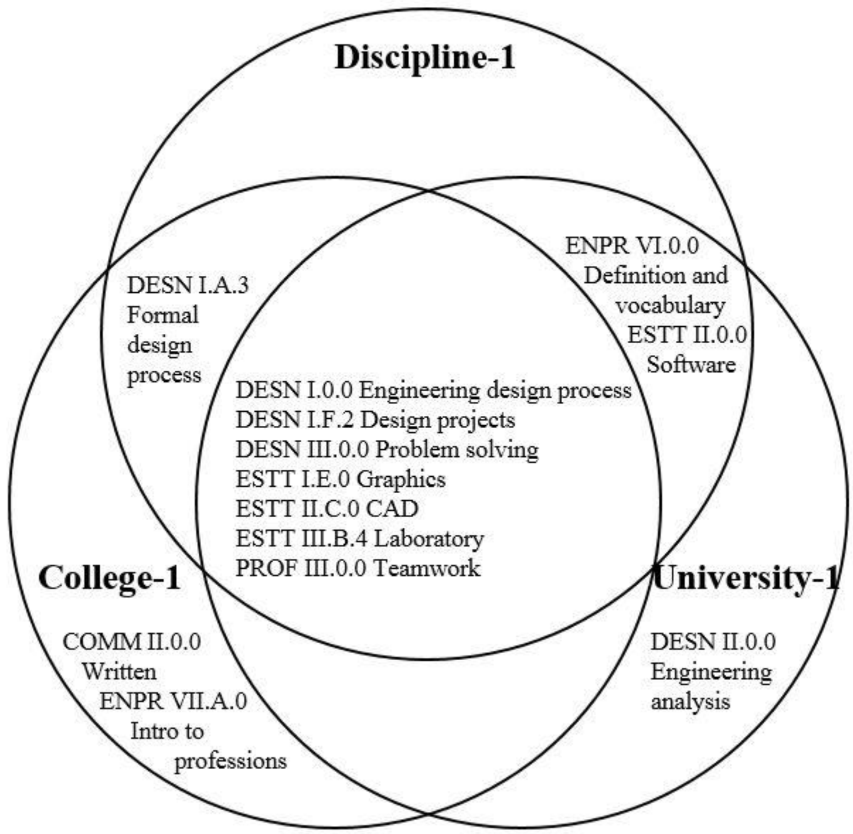

Figure 5.50 Overlaps of the Ten Most Frequently Listed Categories at Discipline-Admitted, College-Admitted, and University-Admitted Institutions with One Accredited Engineering Program

The resemblance of top ten categories among institutions with different matriculation models suggests that content selection of first-year engineering courses is fairly homogenous nationally, regardless of how institutions admit incoming students into the engineering major. Deriving results from course description analysis, this study confirms and generalizes the findings of Brannan and Wankat (2005) that the first-year curricula of *College*-admitted programs are rather standardized in terms of content selection. While taking a closer look at the differences of top ten categories between institutions with multiple accredited programs and institutions with one accredited program, this study finds that students at institutions with one accredited program had fewer chances to explore different engineering subfields than students at institutions with multiple engineering programs.

5.4 Institutional Characteristics by Matriculation Model

As mentioned in Section 4.1.2, data were available for most of the institutional variables listed in Table 4.1 for 404 out of 408 institutions. Among 404 institutions, 283 were *Discipline*-admitted institutions, 74 were *College*-admitted institutions, 43 were *University*-admitted institutions, and 4 institutions were undetermined. The four undetermined institutions were eliminated from this part of study due to missing information on the matriculation model. Consequentially, the final sample size for the study of institutional characteristics by matriculation model was 400 institutions. For the sake of brevity, the following notations are used to present and discuss results in this section:

1. *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions are denoted as D, C, and U respectively.
2. *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions with multiple accredited engineering programs are denoted as D-m, C-m, and U-m respectively.
3. *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions with one accredited engineering program are denoted as D-1, C-1, and U-1 respectively.

4. Institutions with multiple accredited engineering programs were denoted as *-m, and institutions with one accredited engineering program are denoted as *-1.
5. The symbol “>” goes in between two notations symbolizes that the value of the first notation is larger than the value of the second notation.
6. The symbol “≥” goes in between two notations symbolizes that the value of the first notation is larger than the value of the second notation, but the difference between the two values is very small.

❖ **Institutional Control**

- The percentage of public institutions

  C>D>U (C-m>D-m>U-m, C-1>D-1>U-1, *-m>*-1) (Table 5.8)

Table 5.8 Institutional Control by Institutions with Different Matriculation Models (Number of Institutions = 400)

Number of Accredited Program at Institution	Matriculation Model	Public		Private	
		Count	%	Count	%
Overall	Discipline	174	61.48%	109	38.52%
	College	52	70.27%	22	29.73%
	University	24	55.81%	19	44.19%
Multiple Programs	Discipline	146	64.32%	81	35.68%
	College	49	71.01%	20	28.99%
	University	15	62.50%	9	37.50%
One Program	Discipline	28	50.00%	28	50.00%
	College	3	60.00%	2	40.00%
	University	9	47.37%	10	52.63%

❖ **Institutional Type**

- Carnegie Basic Classification
  - The percentage of institutions that are research and doctoral universities

C>D>U (C-m>D-m>U-m, C-1>D-1>U-1, *-m>*-1) Figure 5.51 shows the frequency distributions of *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions respectively.

- The percentage of institutions that are master's colleges and universities U>D>C (D-m≥U-m>C-m, C-1>D-1>U-1, *-1>*-m) (Figure 5.51)
- The percentage of institutions that are baccalaureate and associate's colleges U>D>C (U-m>D-m>C-m, U-1>D-1>C-1, *-1>*-m) (Figure 5.51)

- Highest Level of Degree Offered
  - The percentage of institutions that offer doctoral degree as the highest degree C>D>U (C-m>D-m>U-m, D-1>U-1>C-1, *-m>*-1) (Table 5.9)
  - The percentage of institutions that offer master's degree and post-master's certificate as the highest degree U>D>C (D-m>U-m>C-m, C-1>D-1>U-1, *-1>*-m) (Table 5.9)
  - The percentage of institutions that offer bachelor's degree and post-baccalaureate certificate as the highest degree U>D>C (U-m>C-m≥D-m, U-1>D-1>C-1, *-1>*-m) (Table 5.9)

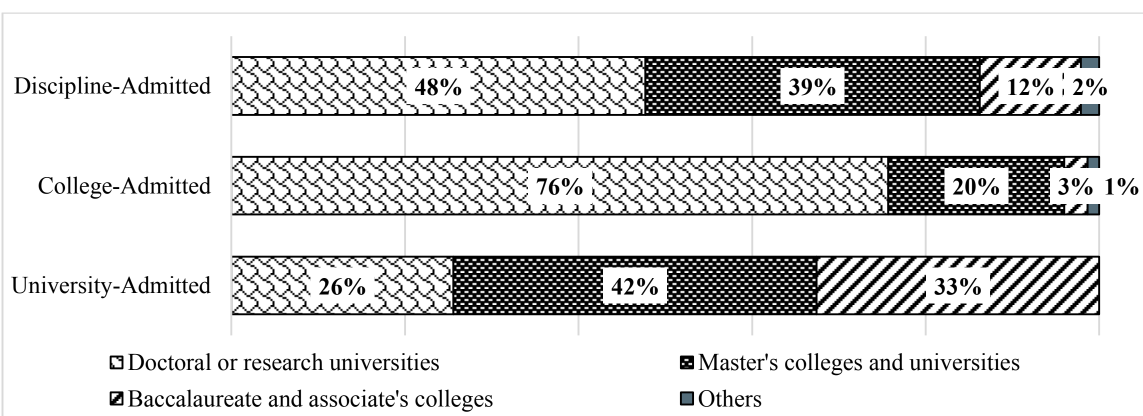

Figure 5.51 Carnegie Basic Classifications of Institutions with Different Matriculation Models (Number of Institutions = 400)

Table 5.9 The Highest Degree Offered by Institutions with Different Matriculation Models (Number of Institutions = 400)

Number of Accredited Program at Institution	Matriculation Model	Doctoral Degree		Master's Degree & Post-Master's Certificate		Bachelor's Degree & Post-Baccalaureate Certificate	
		Count	%	Count	%	Count	%
Overall	Discipline	219	77.39%	54	19.08%	10	3.53%
	College	65	87.84%	7	9.46%	2	2.70%
	University	26	60.47%	9	20.93%	8	18.60%
Multiple programs	Discipline	189	83.26%	33	14.54%	5	2.20%
	College	63	91.30%	4	5.80%	2	2.90%
	University	17	70.83%	3	12.50%	4	16.67%
One program	Discipline	30	53.57%	21	37.50%	5	8.93%
	College	2	40.00%	3	60.00%	–	–
	University	9	47.37%	6	31.58%	4	21.05%

❖ **Degree of Urbanization**

- C>D and C>U (C-m>D-m≥U-m, U-1>D-1 and U-1>C-1, *-m>*-1) (Table 5.10). Direct comparison of the degree of urbanization between *Discipline*-admitted institutions and *University*-admitted institutions could not be made. Specifically, *Discipline*-admitted institutions had higher percentages of institutions located in city, town, and rural area. While *University*-admitted institutions had a higher percentage of institutions located in suburb area (a lower degree of urbanization than city but a higher degree of urbanization than town and rural area).

Table 5.10 Degree of Urbanization by Institutions with Different Matriculation Models (Number of Institutions = 400)

Number of Accredited Program at Institution	Matriculation Model	City		Suburb		Town		Rural	
		Count	%	Count	%	Count	%	Count	%
Overall	Discipline	169	59.72%	56	19.79%	49	17.31%	9	3.18%
	College	48	64.86%	18	24.32%	8	10.81%	–	–
	University	21	48.84%	14	32.56%	7	16.28%	1	2.33%
Institutions with Multiple Programs	Discipline	144	63.44%	46	20.26%	31	13.66%	6	2.64%
	College	46	66.67%	17	24.64%	6	8.70%	–	–
	University	12	50.00%	8	33.33%	3	12.50%	1	4.17%
Institutions with One program	Discipline	25	44.64%	10	17.86%	18	32.14%	3	5.36%
	College	2	40.00%	1	20.00%	2	40.00%	–	–
	University	9	47.37%	6	31.58%	4	21.05%	–	–

❖ **Selectivity**

- Acceptance rate (the number of accepted students divided by the number of applicants)

  D>C>U (D-m>C-m>U-m, D-1>U-1≥C-1, *-1>*-m) Average acceptance rates for *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions were 65%, 57%, and 49% respectively. Average acceptance rates for D-m, C-m, and U-m were 64%, 57%, and 41% respectively. Average acceptance rates for D-1, C-1, and U-1 were 69%, 57%, and 59% respectively.

- Enrollment rate (the number of students who actually attended divided by the number of accepted students)

  U>C>D (U-m>C-m>D-m, C-1>U-1>D-1, *-m≥*-1) Average enrollment rates for *Discipline*-admitted, *College*-admitted, and *University*-admitted institutions were 34%, 39%, and 43% respectively. Average enrollment rates for D-m, C-m, and U-m were 34%, 39%, and 48% respectively. Average enrollment rates for D-1, C-1, and U-1 were 34%, 40%, and 37% respectively.

❖ **Size**

- Total students enrolled, total undergraduate students enrolled, total first-time full-time degree/certificate-seeking undergraduate students enrolled, total engineering students enrolled, total undergraduate engineering students enrolled, total first-time full-time degree/certificate-seeking undergraduate engineering students enrolled, total engineering bachelor's degrees granted
  C>D>U (C-m>D-m>U-m, C-1>D-1>U-1, *-m>*-1) (Table 5.11). For *University*-admitted institutions, the number of first-time full-time degree/certificate-seeking undergraduate engineering students enrolled should be interpreted cautiously because first-time students who want to pursue engineering are not recognized as engineering students at the beginning of their college life. All incoming students are "held" by *University*-admitted institutions in the same place regardless of their intended major choices.
- Engineering students as a percentage of total enrollment, undergraduate engineering students as a percentage of total enrollment
  C>D>U (U-m>C-m>D-m, D-1>C-1>U-1, *-m>*-1) (Table 5.11). Table 5.12 shows that *University*-admitted institutions were more diversified than *Discipline*-admitted and *College*-admitted institutions. Specifically, *University*-admitted institutions had the highest proportions of institutions with less than 10% of engineering students/undergraduate engineering students enrolled. Meanwhile,

they had the highest proportions of institutions with at least 20% of engineering students/undergraduate engineering students enrolled.

- First-time full-time degree/certificate-seeking undergraduate engineering students as a percentage of total enrollment

  C>D>U (D-m≥C-m>U-m, C-1>D-1>U-1, *-m>*-1) (Table 5.11). Again, the percentage for *University*-admitted institutions should be interpreted with caution because incoming students interested in engineering are not formally admitted to the college/school/department that includes engineering programs.
- Total bachelor's degrees granted

  C>D>U (C-m>D-m>U-m, C-1>U-1≥D-1, *-m>*-1) (Table 5.11)
- Total master's degrees granted (excluded institutions that did not offer master's degree)

  C>D>U (C-m>D-m>U-m, U-1>C-1>D-1, *-m>*-1) (Table 5.11)
- Total doctoral degrees granted (excluded institutions that did not offer doctoral degree)

  C>D≥U (C-m>U-m≥D-m, U-1>D-1>C-1, *-m>*-1) (Table 5.11). Table 5.13 shows that *University*-admitted institutions were more diversified than *Discipline*-admitted and *College*-admitted institutions. Specifically, *University*-admitted institutions had the highest proportions of institutions with fewer than 100 doctoral degrees granted. Also, they had the highest proportions of institutions with at least 1,000 doctoral degrees granted.
- Engineering bachelor's degrees as a percentage of total degrees granted

  U≥C>D (U-m>C-m≥D-m, D-1>U-1>C-1, *-m>*-1) (Table 5.11)

- The average number of ABET EAC-accredited programs

  C>D>U (Table 5.11)

Table 5.11 Institutional Size by Institutions with Different Matriculation Models

Institutional Size	Number of Accredited Program at Institution	Matriculation Model	Average Number or Percentage
Total Students Enrolled	Overall	Discipline	14584
		College	20465
		University	8766
	Multiple programs	Discipline	16574
		College	21221
		University	10810
	One program	Discipline	6553
		College	10032
		University	6185
Total Undergraduate Students Enrolled	Overall	Discipline	11304
		College	15483
		University	6407
	Multiple programs	Discipline	12748
		College	15999
		University	7831
	One program	Discipline	5480
		College	8369
		University	4607
Total First-Time Full-Time Degree/Certificate-Seeking Undergraduate Students Enrolled	Overall	Discipline	1974
		College	2692
		University	1266
	Multiple programs	Discipline	2234
		College	2773
		University	1527
	One program	Discipline	923
		College	1578
		University	918
Total Engineering Students Enrolled	Overall	Discipline	1510
		College	2331
		University	834
	Multiple programs	Discipline	1837
		College	2478
		University	1338
	One program	Discipline	197
		College	330
		University	163

Table 5.11 continued.

Institutional Size	Number of Accredited Program at Institution	Matriculation Model	Average Number or Percentage
Total Undergraduate Engineering Students Enrolled	Overall	Discipline	1193
		College	1740
		University	566
	Multiple programs	Discipline	1445
		College	1845
		University	886
	One program	Discipline	180
		College	319
		University	140
Total First-Time Full-Time Degree/Certificate-Seeking Undergraduate Engineering Students Enrolled	Overall	Discipline	265
		College	353
		University	97
	Multiple programs	Discipline	319
		College	371
		University	149
	One program	Discipline	47
		College	108
		University	28
Engineering Students as a Percentage of Total Enrollment	Overall	Discipline	12.37%
		College	14.11%
		University	11.86%
	Multiple programs	Discipline	13.61%
		College	14.69%
		University	18.11%
	One program	Discipline	7.39%
		College	6.21%
		University	3.53%
Undergraduate Engineering Students as a Percentage of Total Enrollment	Overall	Discipline	13.14%
		College	14.86%
		University	11.86%
	Multiple programs	Discipline	14.50%
		College	15.44%
		University	17.90%
	One program	Discipline	7.69%
		College	6.97%
		University	3.80%
First-Time Full-Time Degree/Certificate-Seeking Undergraduate Engineering Students as a Percentage of Total Enrollment	Overall	Discipline	15.70%
		College	16.41%
		University	7.71%
	Multiple programs	Discipline	17.30%
		College	16.51%
		University	11.77%

Table 5.11 continued.

Institutional Size	Number of Accredited Program at Institution	Matriculation Model	Average Number or Percentage
First-Time Full-Time Degree/Certificate-Seeking Undergraduate Engineering Students as a Percentage of Total Enrollment	One program	Discipline	9.29%
		College	15.03%
		University	2.29%
Total Bachelor's Degrees Granted	Overall	Discipline	2334
		College	3357
		University	1452
	Multiple programs	Discipline	2675
		College	3476
		University	1774
	One program	Discipline	957
		College	1704
		University	1045
Total Master's Degrees Granted	Overall	Discipline	872
		College	1333
		University	747
	Multiple programs	Discipline	994
		College	1395
		University	905
	One program	Discipline	348
		College	515
		University	537
Total Doctoral Degrees Granted	Overall	Discipline	290
		College	432
		University	275
	Multiple programs	Discipline	324
		College	443
		University	325
	One program	Discipline	78
		College	71
		University	181
Total Engineering Bachelor's Degrees Granted	Overall	Discipline	186
		College	311
		University	123
	Multiple programs	Discipline	227
		College	331
		University	201
	One program	Discipline	19
		College	33
		University	25

Table 5.11 continued.

Institutional Size	Number of Accredited Program at Institution	Matriculation Model	Average Number or Percentage
Engineering Bachelor's Degrees as a Percentage of Total Degrees Granted	Overall	Discipline	11.03%
		College	12.37%
		University	12.40%
	Multiple programs	Discipline	12.36%
		College	13.00%
		University	19.01%
	One program	Discipline	5.65%
		College	3.64%
		University	4.05%
Number of ABET EAC-Accredited Programs	Overall	Discipline	4.68
		College	6.43
		University	3.37

Table 5.12 Frequency Distribution of Engineering Students and Undergraduate Engineering Students as Percentages of Total Enrollment by Institutions with Different Matriculation Models (Number of Institutions = 396)

Institutional Size	Matriculation Model	<10%	10-19%	≥20%
Engineering Students as a Percentage of Total Enrollment	Discipline	56.22%	31.32%	12.46%
	College	46.58%	35.62%	17.81%
	University	64.29%	14.29%	21.43%
Undergraduate Engineering Students as a Percentage of Total Enrollment	Discipline	54.80%	30.61%	14.59%
	College	43.84%	39.73%	16.44%
	University	64.29%	14.29%	21.43%

Table 5.13 Frequency Distribution of the Number of Doctoral Degrees Granted by Institutions with Different Matriculation Models (Number of Institutions = 309)

Institutional Size	Matriculation Model	<100	100-499	500-999	≥1,000
Total Doctoral Degrees Granted	Discipline	47.71%	29.82%	16.51%	5.96%
	College	20.00%	46.15%	24.62%	9.23%
	University	61.54%	15.38%	11.54%	11.54%

❖ **Quality**

- Student-faculty ratio

  C≥D>U (D-m≥C-m>U-m, C-1≥D-1>U-1, *-m>*-1) (Table 5.14)

- Average salary per month of full-time, non-medical, instructional staff U≥C>D (U-m>C-m>D-m, U-1>D-1>C-1, *-m>*-1) (Table 5.14). Table 5.15 shows that *University*-admitted institutions were more diversified than *Discipline*-admitted and *College*-admitted institutions regarding average monthly salary per instructional staff. Specifically, *University*-admitted institutions had the highest proportions of institutions within which instructional staff's average salary was less than 7,000 USD. Also, *University*-admitted institutions had the highest proportions of institutions within which instructional staff's average salary was at least 11,000 USD.

Table 5.14 Institutional Quality by Institutions with Different Matriculation Models

Institutional Size	Number of Accredited Program at Institution	Matriculation Model	Average Number or Percentage
Student-Faculty Ratio	Overall	Discipline	16.50%
		College	16.53%
		University	13.51%
	Multiple programs	Discipline	16.72%
		College	16.58%
		University	13.46%
	One program	Discipline	15.61%
		College	15.80%
		University	13.58%
Average Salary per Month of Full-Time, Non-Medical, Instructional Staff	Overall	Discipline	8479
		College	9411
		University	9529
	Multiple programs	Discipline	8764
		College	9579
		University	10058
	One program	Discipline	7336
		College	7099
		University	8860

Table 5.15 Frequency Distribution of Average Monthly Salary of Full-Time, Non-Medical, Instructional Staff by Institutions with Different Matriculation Models (Number of Institutions = 398)

Institutional Size	Matriculation Model	<7,000	7,000-8,999	9,000-10,999	≥11,000
Average Salary per Month of Full-Time, Non-Medical, Instructional Staff	Discipline	20.28%	45.20%	24.20%	10.32%
	College	8.11%	40.54%	31.08%	20.27%
	University	27.91%	25.58%	23.26%	23.26%

❖ **Mission**

- Instructional expenses as a percentage of total expenses

  U≥D>C (D-m>U-m>C-m, C-1≥U-1≥D-1, *-1>*-m) (Table 5.16).

- Research expenses as a percentage of total expenses

  C>D>U (C-m>D-m≥U-m, U-1>D-1>C-1, *-m>*-1) (Table 5.16).

- Public service expenses as a percentage of total expenses

  C>D>U (C-m>D-m>U-m, D-1≥C-1>U-1, *-m>*-1) (Table 5.16).

Table 5.16 Institutional Mission by Institutions with Different Matriculation Models

Institutional Mission	Number of Accredited Program	Matriculation Model	Average Percentage
Instructional Expenses as a Percentage of Total Expenses	Overall	Discipline	35.82%
		College	33.61%
		University	36.09%
	Multiple programs	Discipline	35.74%
		College	33.29%
		University	34.95%
	One program	Discipline	36.17%
		College	37.78%
		University	37.69%
Research Expenses as a Percentage of Total Expenses	Overall	Discipline	9.38%
		College	12.54%
		University	7.35%
	Multiple programs	Discipline	10.98%
		College	13.38%
		University	10.13%
	One program	Discipline	2.74%
		College	1.36%
		University	3.41%

Table 5.16 continued.

Institutional Mission	Number of Accredited Program	Matriculation Model	Average Percentage
Public Service Expenses as a Percentage of Total Expenses	Overall	Discipline	3.19%
		College	4.21%
		University	1.81%
	Multiple programs	Discipline	3.31%
		College	4.36%
		University	2.20%
	One program	Discipline	2.70%
		College	2.27%
		University	1.26%

❖ **Student Services Related Expenditures**

- Student service expenses as a percentage of total expenses

  U≥D>C (U-m>D-m>C-m, C-1≥D-1>U-1, *-1>*-m) (Table 5.17).

- Academic support expenses as a percentage of total expenses

  U≥D≥C (C-m≥D-m>U-m, U-1>D-1>C-1, *-1>*-m) (Table 5.17).

Table 5.17 Student Services Related Expenditures by Institutions with Different Matriculation Models

Institutional Mission	Number of Accredited Program at Institution	Matriculation Model	Average Percentage
Student Service Expenses as a Percentage of Total Expenses	Overall	Discipline	8.76%
		College	7.04%
		University	8.87%
	Multiple programs	Discipline	7.99%
		College	6.67%
		University	8.76%
	One program	Discipline	11.93%
		College	11.96%
		University	9.03%
Academic Support Expenses as a Percentage of Total Expenses	Overall	Discipline	9.23%
		College	9.13%
		University	9.39%
	Multiple programs	Discipline	9.11%
		College	9.21%
		University	8.52%
	One program	Discipline	9.72%
		College	8.18%
		University	10.63%

❖ **Residential Status**

- The percentage of institutions that provide on-campus housing
  C>D>U (U-m>C-m>D-m, C-1>D-1>U-1, *-m>*-1) (Table 5.18). On-campus housing was available at almost every institution that was studied, regardless of the matriculation model of the institution.
- The percentage of institutions that require first-time full-time degree/certificate-seeking students to live on campus
  U>C>D (U-m>C-m>D-m, U-1>D-1>C-1, *-m>*-1) (Table 5.18)

Table 5.18 Residential Status by Institutions with Different Matriculation Models

Residential Status	Number of Accredited Program at Institution	Matriculation Model	Average Percentage
The Percentage of Institutions that Provide On-Campus Housing	Overall	Discipline	97.88%
		College	98.65%
		University	97.67%
	Multiple programs	Discipline	98.24%
		College	98.55%
		University	100.00%
	One program	Discipline	96.43%
		College	100.00%
		University	94.74%
The Percentage of Institutions that Require First-Time Full-Time Degree/Certificate-Seeking Students to Live on Campus	Overall	Discipline	6.00%
		College	14.86%
		University	30.95%
	Multiple programs	Discipline	4.85%
		College	15.94%
		University	37.50%
	One program	Discipline	10.71%
		College	0.00%
		University	22.22%

❖ **Financial Aid**

- Average amount of grant aid received by undergraduate students, average amount of grant aid received by first-time full-time degree/certificate-seeking undergraduate students

  U>C>D (U-m>C-m>D-m, U-1>D-1>C-1, *-m>*-1) (Table 5.19)

- The percentage of undergraduate students receiving Pell Grant

  D>C>U (D-m>C-m≥U-m, D-1≥C-1>U-1, *-1>*-m) (Table 5.19)

- The percentage of first-time full-time degree/certificate-seeking undergraduate students receiving Pell Grant

  D>C≥U (D-m>U-m≥C-m, D-1>C-1>U-1, *-1>*-m) (Table 5.19)

Table 5.19 Financial Aid by Institutions with Different Matriculation Models

Financial Aid	Number of Accredited Program at Institution	Matriculation Model	Average Amount or Percentage
Average Amount of Grant Aid Received by Undergraduate Students	Overall	Discipline	11093
		College	12009
		University	16254
	Multiple programs	Discipline	11124
		College	12257
		University	15790
	One program	Discipline	10966
		College	8588
		University	16743
Average Amount of Grant Aid Received by First-Time Full-Time Degree/Certificate-Seeking Undergraduate Students	Overall	Discipline	11551
		College	12817
		University	17133
	Multiple programs	Discipline	11563
		College	13025
		University	16700
	One program	Discipline	11501
		College	9948
		University	17614
Percentage of Undergraduate Students Receiving Pell Grant	Overall	Discipline	33.78%
		College	29.78%
		University	27.54%

Table 5.19 continued.

Financial Aid	Number of Accredited Program at Institution	Matriculation Model	Average Amount or Percentage
Percentage of Undergraduate Students Receiving Pell Grant	Multiple programs	Discipline	33.12%
		College	29.30%
		University	28.70%
	One program	Discipline	36.43%
		College	36.40%
		University	26.32%
Percentage of First-Time Full-Time Degree/Certificate-Seeking Undergraduate Students Receiving Pell Grant	Overall	Discipline	34.96%
		College	29.51%
		University	28.61%
	Multiple programs	Discipline	33.99%
		College	29.07%
		University	29.20%
	One program	Discipline	38.89%
		College	35.60%
		University	27.94%

While comparing the characteristics of institutions with different matriculation models, this study finds the following correlations between variables:

1. The percentage of public institutions was positively correlated with public service expenses as a percentage of total expenses.
2. The percentage of institutions that are research and doctoral universities in the Carnegie Basic Classification was positively related to the percentage of institutions that offer doctoral degree as the highest degree. These two variables were also positively related to research expenses as a percentage of total expenses.
3. The acceptance rate was negatively related to the enrollment rate.
4. The enrollment size was positively related to the number of degrees granted. They were also positively related to the average number of ABET EAC-accredited programs per institution.

5. Instructional expenses as a percentage of total expenses was negatively related to research expenses as a percentage of total expenses.

Figure 5.52 summarizes the characteristics of institutions with different matriculation models using a selected pool of institutional variables. Other variables analyzed in this research are not presented because they were correlated with the selected variables, as discussed above. In the radar chart (Figure 5.52), a longer distance between a point and the center of the circle suggests a larger value (or a higher percentage) of the associated variable.

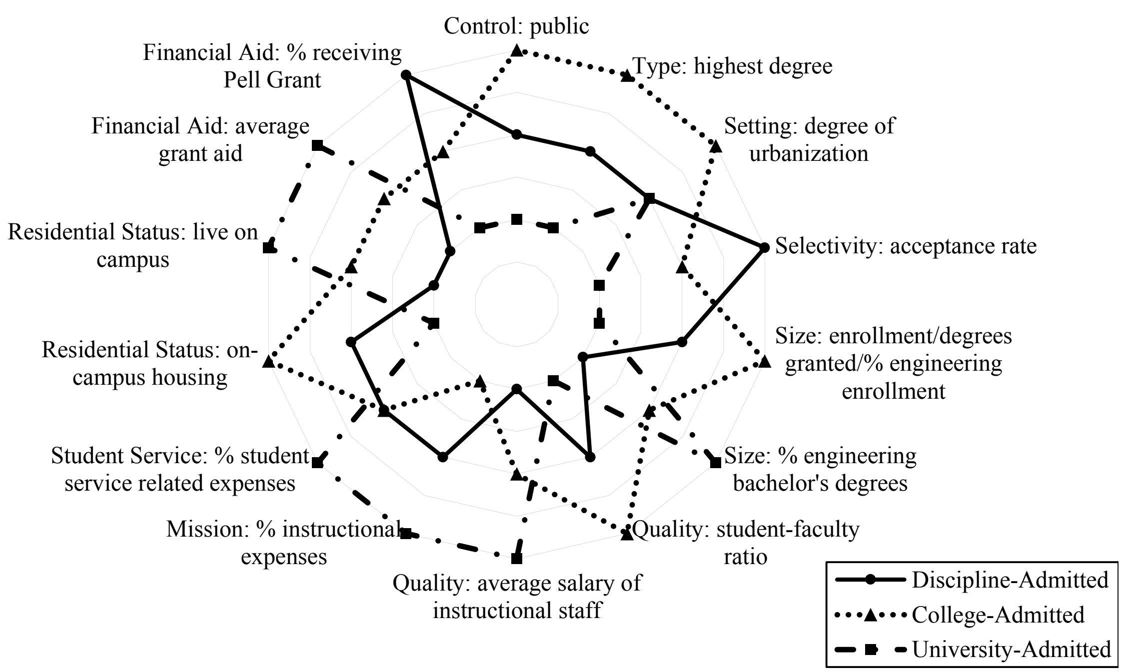

Figure 5.52 Comparison of Key Variables by Institutions with Different Matriculation Models

Discipline-admitted institutions in general had the highest acceptance rate, the lowest percentage of engineering bachelor's degrees granted as a percentage of total degrees granted, the lowest salary for instructional staff, and the lowest percentage of first-time full-time degree-seeking students required to live on campus. While *Discipline*-admitted institutions had the smallest amount of grant aid received by undergraduate students, they had the highest percentage of undergraduate students receiving Pell Grant.

College-admitted institutions were more likely to be public, urban institutions and were more likely to offer doctoral degree as the highest level of degree than *Discipline*- and *University*-admitted institutions. In general, *College*-admitted institutions had the largest enrollment sizes (total students/engineering students, undergraduate students/engineering students, and first-time full-time degree/certificate-seeking undergraduate students/engineering students), the largest numbers of degrees granted (bachelor, master, and PhD), and the highest percentage of engineering students enrolled as a percentage of total enrollment. While *College*-admitted institutions had the highest student-faculty ratio, their percentage of instructional expenses as a percentage of total expenses was the lowest. Last but not least, *College*-admitted institutions had the highest percentage of institutions providing on-campus housing.

University-admitted institutions were more likely to be private institutions, and were more likely to offer bachelor's or master's degree as the highest level of degree than *Discipline*- and *College*-admitted institutions. *University*-admitted institutions were featured to have the lowest acceptance rate, the smallest enrollment sizes, the smallest numbers of degrees granted, and the lowest student-faculty ratio. While *University*-admitted institutions had the lowest percentages of undergraduate engineering student enrollment (12%) and first-time full-time degree/certificate-seeking undergraduate engineering student enrollment (8%) as percentages of total enrollment, they had the highest percentage of engineering bachelor's degrees granted as a percentage of total degrees granted (12%). *University*-admitted institutions had the highest average salary for instructional staff, and the highest percentage of instructional and student service related expenses as a percentage of total expenses. Although *University*-admitted institutions had the lowest percentage of institutions providing on-campus housing, they had the highest percentage of institutions that required first-time full-time degree-seeking students to live on campus. In contrast to *Discipline*-admitted institutions, *University*-admitted institutions had the largest amount of grant aid received by undergraduate students but the lowest percentage of undergraduate students receiving Pell Grant.

On average, *College*-admitted institutions had a larger engineering enrollment and a larger number of engineering bachelor's degrees awarded than *Discipline*-admitted institutions. For instance, *College*-admitted institutions granted an average of 311 engineering bachelor's degrees between July 2011 and June 2012. The average number was 186 for *Discipline*-admitted institutions. However, while considering total engineering enrollment and total engineering bachelor's degrees granted at all institutions grouped by matriculation models, *Discipline*-admitted institutions had significantly larger engineering enrollment and numbers of degrees granted than *College*-admitted institutions. For example, there were 52,474 engineering bachelor's degrees awarded at 282 *Discipline*-admitted institutions with ABET EAC-accredited programs (IPEDS data were unavailable for the remaining 5 *Discipline*-admitted institutions), accounting for nearly 65% of the engineering bachelor's degrees conferred nationally (Snyder & Hoffman, 2013a). The number of engineering bachelor's degrees granted was 22,998 for all *College*-admitted institutions with accredited programs. Notably, although *University*-

admitted institutions had the smallest engineering enrollment, the smallest number of engineering bachelor's degrees awarded, and the lowest percentage of engineering enrollment as a percentage of total enrollment, they managed to grant the highest percentage of engineering bachelor's degrees (as a percentage of total degrees granted).

While institutions were further divided by institutions with multiple accredited programs and institutions with one accredited program, this study finds that *-m had a larger value than *-1 for almost every institutional variable except the following: (1) acceptance rate; (2) the percentage of instructional expenses as a percentage of total expenses; (3) the percentage of student service related expenses as a percentage of total expenses; and (4) the percentage of students receiving Pell Grant. Meanwhile, *-m and *-1 with the same matriculation model were quite different in some aspects. Specifically, D-m had lower percentages of engineering enrollment (as a percentage of total enrollment) and engineering bachelor's degrees granted (as a percentage of total degrees granted) than C-m and U-m. In the opposite direction, D-1 had higher percentages of engineering enrollment and engineering bachelor's degrees granted than C-1 and U-1. On average, C-m had a higher percentage of institutions offering doctoral degree as the highest degree. They also had a larger number of doctoral degrees awarded and a higher percentage of research expenses as a percentage of total expenses than D-m and U-m. Opposite trends exist between C-1 and D-1/U-1. For U-m, they had a lower degree of urbanization, a lower percentage of research expenses as a percentage of total expenses, a higher percentage of engineering enrollment as a percentage of total enrollment, and a higher percentage of institutions providing on-campus housing than D-m and C-m. A comparison between U-1 and D-1/C-1 shows opposite results.

In sum, *Discipline*-admitted institutions were characterized by being the least selective, paying the lowest average salary for instructional staff, being the least likely to require first-time full-time degree-seeking students to live on campus, having the smallest amount of grant aid received by undergraduate students, and having the highest percentage of undergraduate students receiving Pell Grant. Meanwhile, *Discipline*-admitted institutions granted the lowest percentage of engineering bachelor's degrees as a percentage of total degrees granted.

College-admitted institutions were characterized by being large size, public, urban, research universities that were the most likely to offer doctoral degree as the highest level of degree. Their institutional missions were research and public service. *College*-admitted institutions had the highest student-faculty ratio and provided the highest percentage of on-campus housing. Last but not least, *College*-admitted institutions had the largest engineering enrollment and the highest percentage of engineering enrollment as a percentage of total enrollment.

University-admitted institutions were characterized by being small size, private, selective institutions that were the most likely to offer bachelor's or master's degree as the highest degree. They emphasized instruction and had the highest percentage of student service related expenses as a percentage of total expenses. They had the lowest student-faculty ratio and paid the highest average salary for instructional staff. *University*-admitted institutions were the most likely to require first-time full-time degree-seeking students to live on campus, had the largest amount of grant aid received by undergraduate students, and had the lowest percentage of undergraduate students receiving Pell Grant. Although *University*-admitted institutions had the lowest percentage of engineering enrollment as a percentage of total enrollment, they granted the highest percentage of engineering bachelor's degrees as a percentage of total degrees granted.

Previous work of Orr et al. (2012) suggested that first-time engineering students had a higher engineering persistence rate and a shorter time to finish degree at *Discipline*-admitted and *College*-admitted institutions, whereas transfer students and students switched from other majors were more likely to enter engineering and graduate at *University*-admitted institutions. Findings of this study extends that work by noting that *University*-admitted institutions managed to award a higher percentage of engineering bachelor's degrees (as a percentage of total bachelor's degrees granted) though they had a lower percentage of engineering enrollment (as a percentage of total enrollment) than *Discipline*-admitted and *College*-admitted institutions. Seemingly, *University*-admitted institutions provide an educational environment that is more likely to be associated with desired engineering student outcomes.

Institutions with different matriculation models had distinct characteristics, demonstrating the existence of connections between institution-level and unit-level variables (Figure 2.1). As the Model of Academic Plans in Context (Lattuca & Stark, 2009) suggests, institution-level variables and unit-level variables interactively influence the development of an undergraduate curriculum. Consequently, both conventional institutional characteristics examined in this study, such as institutional control and various types of institutional expenses, and the matriculation model of an engineering program should be considered when administrators and course designers make revisions to the existing engineering curriculum.

CHAPTER 6. CONCLUSIONS

This chapter starts with a restatement of the research purpose and research questions, followed by a brief summary of the answers to research questions. Implications and limitations of this study are discussed. Finally, recommendations for future research are provided.

6.1 Summary

The purpose of this study was to provide a snapshot of the composition of first-year engineering curricula and to determine its relationships to matriculation models and institutional characteristics. This study was guided by the following research questions:

1. How are the current first-year engineering curricula comprised by the following five categories of courses at institutions with ABET EAC-accredited programs?
    - Engineering
    - Mathematics
    - Science
    - Computer science
    - General education or free electives
2. What are the characteristics of a first-year engineering course regarding the following aspects:

- The course is mandatory, elective (chosen from a number of courses, required), or optional (recommended but not required) for first-year engineering students
- The course is designed for engineering students in general or for students in specific engineering subfield(s)
- The term in which the course is expected to be taken

3. What subjects are considered by engineering programs to be the foundational knowledge in first-year engineering courses?
4. How do first-year engineering curricula and institutional characteristics differ by matriculation models?

The theoretical framework that guided this study was the *Model of Academic Plans in Context* developed by Lattuca and Stark (2009). To answer the research questions, this study analyzed the recommended first-year course sequences of 1,969 engineering programs and descriptions of 2,222 first-year engineering courses at all 408 U.S. institutions with ABET EAC-accredited programs. Keywords extracted from the engineering course descriptions were classified using a revised *First-Year Engineering Course Classification Scheme* (Reid, Reeping, et al., 2013). In addition, this study examined institutional characteristics grouped by matriculation models using data downloaded from IPEDS.

Major findings and conclusions drawn from the results of this study are summarized below. For each finding, the number of the associated research question is provided in front of the paragraph. For the sake of brevity, four research questions of this study are denoted as R1, R2, R3, and R4 respectively.

R1: Measured by the number of credit hours, the average first-year engineering curriculum of all ABET EAC-accredited programs was comprised by five categories of courses: engineering, mathematics, science, computer science, and general education/free electives. Engineering courses took up 14-17% of total credit hours in the first year. Mathematics courses accounted for 25% of total credit hours. Together, science courses and general education/free electives courses took up 55-59% of the first-year credit hours. The proportion of science courses increased by term, whereas the percentage of general education/free electives courses decreased. General education/free electives courses took up the largest percentage of total credits in the first term, accounting for at least 30% of total credit hours. Their percentage was exceeded by the percentage of science courses in the following term(s). Computer science courses only accounted for 2-3% of total credit hours in the first year. The curriculum composition revealed in this study is in accordance with previous studies that mathematics and science still form the foundation in the early engineering curriculum after ABET criteria EC2000 was implemented.

R1, R4: First-year engineering curricula compositions varied by matriculation models. *Discipline*- and *College*-admitted engineering programs offered a significantly higher percentage of engineering courses and a lower percentage of general education/free elective courses than *University*-admitted programs. This finding suggests that first-year students intending to pursue engineering in *University*-admitted programs are given less exposure to the engineering profession, which may affect student retention in these programs. Nevertheless, *University*-admitted programs provide a diverse first-year engineering curriculum characterized by a significantly higher percentage of general education/free elective courses. These programs allow students who are undetermined to clarify their interests and encourage transfer students to migrate into engineering by accepting a wide variety of courses as eligible gateway courses.

R2: Mandatory engineering courses made up most of the engineering course credits. A surprisingly low percentage of elective engineering courses was required in the first year. This finding suggests that engineering programs prefer a structured curriculum in the first year to equip students with a common body of knowledge in engineering, leaving little room for students to choose engineering courses that they are interested in.

R2, R4: The composition of first-year engineering courses also varied by matriculation models. *Discipline*-admitted programs generally required a significantly higher percentage of disciplinary engineering courses than *College*- and *University*-admitted programs. With the highest percentage of disciplinary engineering courses, *Discipline*-admitted programs aim to establish a direct and clear connection between students' personal interests and the career path in their declared discipline. Students either confirm their choice of major or switch to another major that better fit their interests. With a high percentage of general engineering courses, *College*- and *University*-admitted programs intend to increase students' understanding of the engineering profession in general, and expose students to various engineering subfields before they make a formal decision on major selection. Despite difference in the emphasis of general versus disciplinary engineering knowledge, engineering programs of all matriculation models increased the proportion of disciplinary engineering courses by term in the first year. One implication is that incoming students need to determine their engineering major and prepare to take relevant disciplinary courses as early as possible to graduate within four years.

R2, R4: Overall, *Discipline*-admitted and *College*-admitted institutions required students to take the first engineering course earlier than *University*-admitted institutions. For institutions with multiple accredited engineering programs, almost all *Discipline*-admitted and *College*-admitted institutions required the first engineering course at least by some of their accredited programs early in the first term. Only 60% of *University*-admitted institutions did so. While the timetables of requiring the first engineering course were similar between *Discipline*- and *College*-admitted institutions, the two types of institutions had apparently different schedules on the first disciplinary engineering course. *Discipline*-admitted institutions were more likely to require the first disciplinary engineering course in the first term at lease by some accredited programs, while *College*-admitted institutions were more likely to postpone the first disciplinary engineering course until the third term (i.e. the first term in the second year for nearly 90% of the programs). Different schedules of the first engineering course and the first disciplinary engineering course among institutions with different matriculation models may affect engineering student outcomes such as retention and degree completion time.

R3: An analysis of the keywords extracted from course descriptions revealed that topics related to engineering technologies and tools appeared most frequently in first-year engineering course descriptions, followed by topics related to design and the engineering profession. Topics related to academic advising and mathematics were listed less frequently, which was expected because those concepts were usually covered by general education courses and mathematics courses instead of engineering courses. Notably, topics related to global interest were seldom listed, indicating little attention was given to the grand challenges for engineering proposed by NAE. While a number of frequently listed topics mapped onto the student outcomes listed in ABET EC2000 Criterion 3, there was little to no emphasis in first-year engineering course descriptions on the following aspects of knowledge and skills associated with Criterion 3: (1) design criteria and constraints; (2) communicate effectively in realistic settings; (3) awareness of the impact of engineering solutions in a global context; and (4) life-long learning. In addition, this study found a positive relationship between the frequency of a topic listed and the importance of the topic that was rated by senior engineering students. It is possible that first-year engineering course content selection has a long-term influence on students' recognition of critical engineering knowledge and skills. First-year engineering students may interpret the concepts introduced in an introductory engineering course as indications that these concepts are important in engineering.

R3, R4: Institutions with different matriculation models shared the majority of frequently listed categories, suggesting that content selection of first-year engineering courses is fairly homogenous nationally. Compared to students at institutions with multiple accredited engineering programs, students at institutions with one accredited program have fewer chances to explore different engineering subfields when taking first-year engineering courses.

R4: Institutions with different matriculation models had distinct features. *Discipline*-admitted institutions were characterized by being the least selective, paying the lowest average salary for instructional staff, being the least likely to require first-time full-time degree-seeking students to live on campus, having the smallest amount of grant aid received by undergraduate students, and having the highest percentage of undergraduate students receiving Pell Grant. Meanwhile, *Discipline*-admitted institutions granted the lowest percentage of engineering bachelor's degrees (as a percentage of total degrees granted). *College*-admitted institutions were characterized by being large size, public, urban, research universities that were the most likely to offer doctoral degree as the highest degree. Their institutional missions were research and public service. *College*-admitted institutions had the highest student-faculty ratio and provided the highest percentage of on-campus housing. Last but not least, *College*-admitted institutions had the largest engineering enrollment and the highest percentage of engineering enrollment (as a percentage of total enrollment). *University*-admitted institutions were characterized to be small size, private, high-quality, selective institutions that were the most likely to offer bachelor's or master's degree as the highest degree. They emphasized instruction and had the highest percentage of student service related expenses (as a percentage of total expenses). *University*-admitted institutions were the most likely to require first-time full-time degree-seeking students to live on campus, had the largest amount of grant aid received by undergraduate students, and had the lowest percentage of undergraduate students receiving Pell Grant. Although *University*-admitted institutions had the lowest percentage of engineering enrollment (as a percentage of total enrollment), they managed to grant the highest percentage of engineering bachelor's degrees (as a percentage of total degrees granted). Findings demonstrate the existence of relationships between institution-level and unit-level variables shown in the Model of Academic Plans in Context (Lattuca & Stark, 2009). Since institution-level variables and unit-level variables interactively influence the development of an undergraduate curriculum. Both institutional characteristics and the matriculation model of an engineering program should be considered when administrators and course designers make revisions to the existing engineering curriculum.

6.2 Implications

Four practical implications of this study are discussed in this section. First, a relatively low percentage of engineering courses in the first year, especially at *University*-admitted institutions, suggests that engineering programs should use alternative ways, such as advising and extracurricular activities, to facilitate the development of a sense of engineering identity. Academic advisors can help students develop educational plans and select appropriate courses to meet the program's academic requirements. They can also reveal to students the range of careers and identify possible internship opportunities within engineering. Meanwhile, extracurricular activities, such as student chapters of professional engineering societies, can complement the engineering curriculum by increasing students' involvement in engineering.

Second, a small number of topics listed per engineering course description suggests a review of the engineering course descriptions to match the course contents. Although a syllabus offers more updated and complete course information, it is generally not available until the first day of class. Therefore, course descriptions provided in the university catalog are among the primary sources of reference for incoming students to make decision about which course to choose. It will be helpful if engineering programs and the institution provide updated and accurate course descriptions.

Third, results of the course content analysis suggest that curriculum designers should examine if an engineering curriculum covers all knowledge and skills associated with ABET Criterion 3. Particularly, curriculum designers should make sure the coverage of the following topics that are insufficiently listed in the descriptions of first-year engineering courses: the grand challenges for engineering, design criteria and constraints, communication in realistic settings, and life-long learning.

Finally, variations of institutional characteristics among institutions with different matriculation models suggest that engineering program administrators and faculty members should be aware of both institution-level and program-level influences and their interactions as they make course planning decisions.

6.3 Limitations and Future Research

This study is limited in four ways. First, this study is limited in that the curriculum data were extracted from the written requirements of engineering programs instead of engineering students' academic records. The suggested course sequences do not reflect students' diverse course-taking behaviors. Also, questions about the quality of instruction or how well students understand the concepts cannot be answered. Second, engineering course content analysis was based on the descriptions of first-year engineering courses, which may not be a good reflection of what is actually taught in class. Particularly, the average numbers of topics listed per course and per institution calculated in this study should be interpreted with caution. Much larger numbers are expected if keywords are extracted from the course syllabi which provide more details about the coverage of course content, although course syllabi might not reflect what is actually taught in class either. Third, while this study provides a snapshot of the composition of first-year engineering curricula nationally, it cannot tell if any significant changes in the engineering curriculum structure happened historically. Finally, due to a lack of student-level data nationally, this study is not able to determine if relationships exist between contextual factors and engineering student outcomes. Also, other institutional factors that are highly related to student outcomes, such as teaching techniques and faculty-student interaction, are not captured by the data available to this study.

Results of this study suggest several recommendations for future research. First, further study can investigate the relationship between the stated program requirements on course selection and engineering students' actual course planning. Related studies can make a comparison between the suggested course sequences and students' academic transcripts to see if they are closely related to each other. Second, future researchers can examine the suggested course sequences and course contents beyond the first year to get a holistic view of the engineering curriculum. For the engineering course content analysis, a syllabus is a better source of data than a course description by providing more accurate and detailed course information. Third, it may be instructive for future researchers to study the relationships among curriculum structure, matriculation model, institutional characteristics, and engineering student outcomes. Finally, future researchers should consider the development of a classification scheme to classify keywords of undergraduate engineering courses, not only introductory engineering courses. A classification scheme of this type will be useful for instructors to examine if a course addresses ABET outcomes. Also, it provides a language for engineering researchers to describe and compare courses using a common set of terms.

LIST OF REFERENCES

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ABET. (2013a). Criteria for Accrediting Engineering Programs: Effective for Reviews During the 2013-2014 Accreditation Cycle. Retrieved from http://www.abet.org/uploadedFiles/Accreditation/Accreditation_Step_by_Step/Accreditation_Documents/Current/2013_-_2014/eac-criteria-2013-2014.pdf

ABET. (2013b). Find Accredited Programs Retrieved October 3, 2013, from http://main.abet.org/aps/Accreditedprogramsearch.aspx

Adelman, C. (1995). The New College Course Map and Transcript Files: Changes in Course-Taking and Achievement, 1972-1993. Washington, DC: U.S. Department of Education.

Adelman, C. (1998). Women and Men of the Engineering Path: A Model for Analyses of Undergraduate Careers. Washington, DC: U.S. Department of Education: National Institute for Science Education.

Alfred University. (2013). Undergraduate Catalog 2013-2014 Retrieved October, 22, 2013, from http://www.alfred.edu/academics/docs/undergrad-catalog-13-14/20-ugc-13-14SOECoursesDescription_273-285.pdf

Ambrose, S. A., & Amon, C. H. (1997). Systematic Design of a First-Year Mechanical Engineering Course at Carnegie Mellon University. *Journal of Engineering Education, 86*(2), 173-181.

Anderson-Rowland, M. R. (1998). *The Effect of Course Sequence on the Retention of Freshmen Engineering Students: When Should the Intro Engineering Course be Offered?* Paper presented at the Annual Frontiers in Education Conference, Tempe, AZ.

Arizona State University. (2013). 2013 - 2014 Major Map Aerospace Engineering (Aeronautics), BSE Retrieved November 2, 2013, from https://webapp4.asu.edu/programs/t5/roadmaps/ASU00/ESAEROBSE/2013

Astin, A. W. (1975). *Preventing Students from Dropping Out*. San Francisco, CA: Jossey-Bass.

Astin, A. W. (1993). *What Matters in College? Four Critical Years Revisited*. San Francisco, CA: Jossey-Bass.

Astin, A. W. (1999). Student Involvement: A Developmental Theory for Higher Education. *Journal of College Student Development, 40*(5), 518-529.

Astin, A. W., & Oseguera, L. (2005). Pre-College and Institutional Influences on Degree Attainment. In A. Seidman (Ed.), *College Student Retention: Formula for Student Success* (pp. 245-276). Westport, CT: American Council on Education and Praeger.

Atman, C. J., Sheppard, S. D., Turns, J., Adams, R. S., Fleming, L. N., Stevens, R., . . . Lund, D. (2010). Enabling Engineering Student Success: The Final Report for the Center for the Advancement of Engineering Education. San Rafael, CA: Morgan & Claypool Publishers.

Berger, J. B., & Lyon, S. C. (2005). Past to Present: A Historical Look at Retention. In A. Seidman (Ed.), *College Student Retention: Formula for Student Success* (pp. 1-29). Westport, CT: American Council on Education and Praeger.

Bernold, L. E., Spurlin, J. E., & Anson, C. M. (2007). Understanding Our Students: A Longitudinal-Study of Success and Failure in Engineering With Implications for Increased Retention. *Journal of Engineering Education, 96*(3), 263-274.

Bettinger, E. (2004). How Financial Aid Affects Persistence. In C. M. Hoxby (Ed.), *College Choices: The Economics of Where to Go, When to Go, and How to Pay For It* (pp. 207-237). Chicago, IL: University of Chicago Press.

Bowman, F. M., Balcarcel, R. R., Jennings, G. K., & Rogers, B. R. (2003). Frontiers of Chemical Engineering: A Chemical Engineering Freshman Seminar. *Chemical Engineering Education, 37*(1), 24-29.

Brannan, K. P., & Wankat, P. C. (2005). *Survey of First-Year Programs.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Portland, OR.

Brawner, C. E., Camacho, M. M., Long, R. A., Lord, S. M., Ohland, M. W., & Wasburn, M. H. (2009). *Work in Progress - The Effect of Engineering Matriculation Status on Major Selection.* Paper presented at the Annual Frontiers in Education Conference, San Antonio, TX.

Brawner, C. E., Ohland, M. W., Chen, X., & Orr, M. K. (2013). *The Effect of Matriculation Practices and First-Year Engineering Courses on Engineering Major Selection*. Paper presented at the Annual Frontiers in Education Conference, Oklahoma City, OK.

Budryk, Z. (2013). 'Redshirting' in Engineering Retrieved May 21, 2013, from http://www.insidehighered.com/news/2013/05/20/redshirting-engineering-programs-gain-popularity

California Institute of Technology. (2013). Caltech Catalog 2013-14. Retrieved from http://catalog.caltech.edu/13_14/pdf/catalog_13_14.pdf

Carnegie Foundation for the Advancement of Teaching. (2010). The Carnegie Classification of Institutions of Higher Education. Retrieved from http://classifications.carnegiefoundation.org/

Carnegie Foundation for the Advancement of Teaching. (2014a). The Carnegie Classification of Institutions of Higher Education Retrieved March 15, 2014, from http://classifications.carnegiefoundation.org/

Carnegie Foundation for the Advancement of Teaching. (2014b). Carnegie Classifications FAQs Retrieved March 15, 2014, from http://classifications.carnegiefoundation.org/resources/faqs.php

Chen, X., Brawner, C. E., Ohland, M. W., & Orr, M. K. (2013). *A Taxonomy of Engineering Matriculation Practices*. Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Atlanta, GA.

Chen, X., Brawner, C. E., Orr, M. K., & Ohland, M. W. (2014). *A Taxonomy of Engineering Matriculation Practices and Introductory Engineering Courses.* Poster session presented at the Annual Conference on The First-Year Experience, San Diego, CA.

Courter, S. S., Millar, S. B., & Lyons, L. (1998). From the Students' Point of View: Experiences in a Freshman Engineering Design Course. *Journal of Engineering Education, 87*(3), 283-288.

Coward, H. R., Ailes, C. P., & Bardon, R. (2000). Progress of the Engineering Education Coalitions, Final Report. Arlington, VA: SRI International.

Dowd, A. C. (2004). Income and Financial Aid Effects on Persistence and Degree Attainment in Public Colleges. *Education Policy Analysis Archives, 12*(21).

Fortenberry, N. L., Sullivan, J. F., Jordan, P. N., & Knight, D. W. (2007). Engineering Education Research Aids Instruction. *Science, 31*(7), 1175-1176.

Gansemer-Topf, A. M., & Schuh, J. H. (2003). Instruction and academic support expenditures: An investment in retention and graduation. *Journal of College Student Retention, 5*(2), 135-145.

Gansemer-Topf, A. M., & Schuh, J. H. (2006). Institutional Selectivity and Institutional Expenditures: Examining Organizational Factors that Contribute to Retention and Graduation. *Research in Higher Education, 47*(6), 613-642.

Goenner, C. F., & Snaith, S. M. (2003). Predicting Graduation Rates: An Analysis of Student and Institutional Factors at Doctoral Universities. *Journal of College Student Retention, 5*(4), 409-420.

Hamrick, F. A., Schuh, J. H., & Shelley, M. C. (2004). Predicting Higher Education Graduation Rates from Institutional Characteristics and Resource Allocation. *Education Policy Analysis Archives, 12*(19).

Hansen, W. L. (1983). Impact of Student Financial Aid on Access. In J. Froomkin (Ed.), *The Crisis in Higher Education* (pp. 84-96). New York, NY: Academy of Political Science.

Hatton, D. M., Wankat, P. C., & LeBold, W. K. (1998). The Effects of an Orientation Course on the Attitudes of Freshmen Engineering Students. *Journal of Engineering Education, 87*(1), 23-27.

Hoit, M., & Ohland, M. (1998). The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention. *Journal of Engineering Education, 87*(1), 79-85.

Hoyt, J. (1998). Factors Affecting Student Retention At UVSC. Orem, UT: Utah Valley State College.

Hurtado, S., Astin, A. W., & Dey, E. L. (1991). Varieties of General Education Programs: An Empirically Based Taxonomy. *Journal of General Education, 40*, 133-162.

Jamelske, E. (2009). Measuring the Impact of a University First-Year Experience Program on Student GPA and Retention. *Higher Education, 57*(3), 373-391.

Jarosz, J. P., & Busch-Vishniac, I. J. (2006). A Topical Analysis of Mechanical Engineering Curricula. *Journal of Engineering Education, 95*(3), 241-248.

Kane, T. J. (1995). Rising Public College Tuition and College Entry: How Well Do Public Subsidies Promote Access to College? (Working paper series No. 5146). Cambridge, MA: National Bureau of Economic Research.

Knight, D. B. (2014). Reversing the Logic An Outcomes-Based Student Typology for Determining "What Works" in Promoting an Array of Engineering-Related Student Learning Outcomes. *Educational Evaluation and Policy Analysis, 36*(2), 145-169.

Landis, R. B. (1992). *Improving Student Success Through a Model "Introduction to Engineering" Course.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Toledo, OH.

Lattuca, L. R., & Stark, J. S. (2009). *Shaping the College Curriculum: Academic Plans in Context* (2 ed.). San Francisco, CA: Jossey-Bass.

Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). Engineering Change - A Study of the Impact of EC2000, Executive Summary. Baltimore, MD: ABET.

Lounsbury, J. W., & DeNeui, D. (1995). Psychological Sense of Community on Campus. *College Student Journal, 29*, 270-277.

Min, Y., Zhang, G., Long, R. A., Anderson, T. J., & Ohland, M. W. (2011). Nonparametric Survival Analysis of the Loss Rate of Undergraduate Engineering Students. *Journal of Engineering Education, 100*(2), 349-373.

Morrison, C., Griffin, K., & Marcotullio, P. (1995). Retention of Minority Students in Engineering: Institutional Variability and Success *NACME Research Letter* (Vol. 5, pp. 1-20). New York, NY: National Action Council for Minorities in Engineering.

Mourtos, N. J., & Furman, B. J. (2002). *Assessing the Effectiveness of an Introductory Engineering Course for Freshmen.* Paper presented at the Annual Frontiers in Education Conference, Boston, MA.

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

National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press.

National Academy of Engineering. (2014). Grand Challenges Retrieved June 28, 2014, from http://www.engineeringchallenges.org/cms/challenges.aspx

Ohland, M. W., Rajala, S. A., & Anderson, T. J. (2001). *SUCCEED-Sponsored Freshman Year Engineering Curriculum Improvements at NC State: A Longitudinal Study of Retention.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Albuquerque, NM.

Ohland, M. W., Sheppard, S. D., Lichtenstein, G., Eris, O., Chachra, D., & Layton, R. A. (2008). Persistence, Engagement, and Migration in Engineering Programs. *Journal of Engineering Education, 97*(3), 259-278.

Ohland, M. W., Yuhasz, A. G., & Sill, B. L. (2004). Identifying and Removing a Calculus Prerequisite as a Bottleneck in Clemson's General Engineering Curriculum. *Journal of Engineering Education, 93*(3), 253-257.

Orr, M. K., Brawner, C. E., Ohland, M. W., & Layton, R. A. (2013). *The Effect of Required Introduction to Engineering Courses on Retention and Major Selection.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Atlanta, GA.

Orr, M. K., Ohland, M. W., Long, R. A., Lord, S. M., Brawner, C. E., & Layton, R. A. (2012). *Engineering Matriculation Paths: Outcomes of Direct Matriculation, First-Year Engineering, and Post-General Education Models*. Paper presented at the Annual Frontiers in Education Conference, Seattle, WA.

Oseguera, L. (2005). Four and Six-Year Baccalaureate Degree Completion by Institutional Characteristics and Racial/Ethnic Groups. *Journal of College Student Retention, 7*(1-2), 19-59.

Pascarella, E. T., & Terenzini, P. T. (1991). *How College Affects Students: Findings and Insights from Twenty Years of Research*. San Francisco, CA: Jossey-Bass.

Pascarella, E. T., & Terenzini, P. T. (2005). *How College Affects Students: A Third Decade of Research*. San Francisco, CA: Jossey-Bass.

Pike, G. R., Smart, J. C., Kuh, G. D., & Hayek, J. C. (2006). Educational Expenditures and Student Engagement: When Does Money Matter? *Research in Higher Education, 47*(7), 847-872.

Porter, R. L., & Fuller, H. (1997). *A New "Contact-Based" First Year Engineering Course.* Paper presented at the Annual Frontiers in Education Conference, Pittsburgh, PA.

Purdue University. (2014a). First-Year Engineering at Purdue Retrieved June15, 2014, from https://engineering.purdue.edu/ENE/Academics/FirstYear

Purdue University. (2014b). First-Year Engineering Program Retrieved June15, 2014, from https://engineering.purdue.edu/OFE

Reid, K. J., Hertenstein, T. J., Fennell, G. T., & Reeping, D. (2013). *Development of a First-Year Engineering Course Classification Scheme.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Atlanta, GA.

Reid, K. J., Reeping, D., & Spingola, L. (2013). Classification Scheme for First Year Engineering Courses Retrieved September 27, 2013, from http://www2.onu.edu/~k-reid/nsf/index.html

Ro, H. K., Terenzini, P. T., & Yin, A. C. (2013). Between-College Effects on Students Reconsidered. *Research in Higher Education, 54*(3), 253-282.

Rock, D. A., Centra, J. A., & Linn, R. L. (1970). Relationships between College Characteristics and Student Achievement. *American Educational Research Journal, 7*, 109-121.

Russell, J. S., & Stouffer, W. B. (2005). Survey of the National Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education and Practice, 131*(2), 118-128.

Ryan, J. F. (2004). The Relationship between Institutional Expenditures and Degree Attainment at Baccalaureate Colleges. *Research in Higher Education, 45*(2), 97-114.

Schreiner, L. A. (2009). Linking Student Satisfaction and Retention. Retrieved from https://www.faculty.uwstout.edu/admin/provost/upload/LinkingStudentSatis0809.pdf

Scott, M., Bailey, T., & Kienzl, G. (2006). Relative Success? Determinants of College Graduation Rates in Public and Private Colleges in the U.S. *Research in Higher Education, 47*(3), 249-279.

Seftor, N. S., & Turner, S. E. (2002). Back to School: Federal Student Aid Policy and Adult College Enrollment. *Journal of Human Resources, 37*, 336-352.

Seymour, E., & Hewitt, N. M. (1997). *Talking about Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating Engineers: Designing for the Future of the Field*. San Francisco, CA: Jossey-Bass.

Smart, J. C., Ethington, C. A., Riggs, R. O., & Thompson, M. D. (2002). Influences of Institutional Expenditure Patterns on the Development of Students' Leadership Competencies. *Research in Higher Education, 43*(1), 115-132.

Snyder, T. D., & Hoffman, C. M. (2013a). Bachelor's, Master's, and Doctor's Degrees Conferred by Postsecondary Institutions, by Sex of Student and Discipline Division: 2011-12. *Digest of Education Statistics: 2013*. Retrieved from http://nces.ed.gov/programs/digest/d13/tables/dt13_318.30.asp

Snyder, T. D., & Hoffman, C. M. (2013b). *Digest of Education Statistics: 2013*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Snyder, T. D., & Hoffman, C. M. (2013c). Number of Postsecondary Institutions Conferring Degrees, by Control of Institution, Level of Degree, and Field of Study: 2011-12. *Digest of Education Statistics: 2013*. Retrieved from http://nces.ed.gov/programs/digest/d13/tables/dt13_318.60.asp

Solmon, L. C. (1975). The Definition of College Quality and Its Impact on Earnings. *Explorations in Economic Research, 2*(4), 537-587.

Somers, P. A. (1994). The Effect of Price on Within-Year Persistence. *Journal of Student Financial Aid, 24*(1), 31-45.

St. John, E. P., Kirshstein, R. J., & Noell, J. (1991). The Effects of Student Financial Aid on Persistence: A Sequential Analysis. *Review of Higher Education, 14*(3), 383-406.

Stephan, K. D. (1999). A Survey of Ethics-Related Instruction in U.S. Engineering Programs. *Journal of Engineering Education, 88*(4), 459-464.

The Steering Committee of the National Engineering Education Research Colloquies. (2006). The National Engineering Education Research Colloquies (Special Report). *Journal of Engineering Education, 95*(4), 257-258.

Tinto, V. (1975). Dropout from Higher Education: A Theoretical Synthesis of Recent Research. *Review of Educational Research, 45*(1), 89-125.

Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition* (Second ed.). Chicago, IL: University of Chicago Press.

Titus, M. A. (2004). An Examination of the Influence of Institutional Context on Student Persistence at 4-Year Colleges and Universities: A Multilevel Approach. *Research in Higher Education, 45*(7), 673-699.

Toutkoushian, R. K., & Smart, J. C. (2001). Do Institutional Characteristics Affect Student Gains from College? *Review of Higher Education, 25*(1), 39-61.

Tsui, L. (2007). Effective Strategies to Increase Diversity in STEM Fields: A Review of the Research Literature. *Journal of Negro Education, 76*(4), 555-581.

Tyson, W. (2011). Modeling Engineering Degree Attainment Using High School and College Physics and Calculus Coursetaking and Achievement. *Journal of Engineering Education, 100*(4), 760-777.

U.S. Department of Education. (2012). The Integrated Postsecondary Education Data System (IPEDS). Retrieved November 3, 2013 http://nces.ed.gov/ipeds/datacenter/DataFiles.aspx

University of Houston Clear Lake. (2013). Student Handbook for Computer Engineering B.S. 2012-2013. Retrieved from http://prtl.uhcl.edu/portal/page/portal/SCE/Engineering/ENGIN_Documents/ceng_handbook.pdf

Volkwein, J. F., & Szelest, B. P. (1995). Individual and Campus Characteristics Associated with Student Loan Default. *Research in Higher Education, 36*(1), 41-72.

Watson, H., Pierrakos, O., & Newbold, T. (2010). *Research to Practice: Using Research Findings to Inform the First-Year Engineering Experience.* Paper presented at the Annual Frontiers in Education Conference, Washington, DC.

Zimmerman, J. B., & Vanegas, J. (2007). Using Sustainability Education to Enable the Increase of Diversity in Science, Engineering and Technology-Related Disciplines. *International Journal of Engineering Education, 23*(2), 242-253.

APPENDICES

Appendix A A First-Year Engineering Course Classification Scheme

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Academic Advising →Community	ACAD I.0.0	
Academic Advising →Community →Relationships and Friendships	ACAD I.A.0	Development of working relationships is fostered in the classroom environment and in project groups to develop long lasting friendships.
Academic Advising →Personal Management	ACAD II.0.0	
Academic Advising →Personal Management →Time Management	ACAD II.A.0	Personal responsibility is stressed and students are given advice on how to manage their workload and balance school with their personal life.
Academic Advising →Personal Management →Stress Management	ACAD II.B.0	Students are introduced to methods of relieving stress and/or oriented to the campus health center.
Academic Advising →E-Portfolio Design	ACAD III.0.0	Students are introduced to methods of developing an online professional presence. Students are then tasked to create their own profile. This outcome is tied with COMM II.C.0 (Resume).
Academic Advising →Academic Integrity	ACAD IV.0.0	It is made clear to the students that cheating is not tolerated. This outcome is tied with PROF II.0.0 (Ethics) if the ethics behind dishonesty in the workplace is addressed as well.
Academic Advising →Advising	ACAD V.0.0	
Academic Advising →Advising →Plan of Study	ACAD V.A.0	Students develop their own plan of study and pick which path is the best fit for their interests.
Academic Advising →Advising →Study Abroad	ACAD V.B.0	Students are oriented to the ability to travel abroad and study for credit in foreign countries.
Academic Advising →Advising →Co-op or Internship	ACAD V.C.0	Students are introduced to the option to co-op or be an intern during the summer or school year.
Academic Advising →Advising →Co-op or Internship →Interviews	ACAD V.C.1	The ability for students to practice through mock interviews is offered.
Academic Advising →Advising →Introduction to Campus	ACAD V.D.0	Students are given an introduction to the campus (may or may not involve a tour).
Academic Advising →Advising →Introduction to Departments	ACAD V.E.0	Each department in the College of Engineering is represented to the students and each major is given a proper introduction.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Academic Advising →Advising →Undergraduate Research	ACAD V.F.0	Students participate in undergraduate research.
Academic Advising →Lifelong Learning	ACAD VI.0.0	The mindset of learning throughout one's life (even when one is no longer in school) is fostered.
Academic Advising →Choice of Major	ACAD VII.0.0	Analysis of the student's commitment to their specific major is conducted by the student's advisor. This outcome is tied with ENPR VIII.0.0 (Commitment to Discipline) if students are encouraged to specify a major based on career plans.
Communication →Professional	COMM I.0.0	
Communication →Professional →Client Interactions	COMM I.A.0	Students have professional meetings with donors or senior project sponsors. These students are prepped for professional situations.
Communication →Written	COMM II.0.0	
Communication →Written →Reports	COMM II.A.0	
Communication →Written →Reports →Lab	COMM II.A.1	Students are required to write a report summarizing their results and/or discoveries during a lab session.
Communication →Written →Reports →Documentation	COMM II.A.2	Students keep a lab notebook or collection of papers from lab work or design projects. Each group or individual must write agendas for meetings and keep an organized portfolio for larger projects.
Communication →Written →Reports →Engineering	COMM II.A.3	Students write about a design project, summarizing their design process and methods. These reports will cover topics such as: construction of a device, criteria and constraints, design alternatives, and prototypes.
Communication →Written →Email Writing	COMM II.B.0	Students learn the basics of writing a professional email.
Communication →Written →Resume	COMM II.C.0	Students develop a working resume to be used when applying for internships, co-ops, or job opportunities.
Communication →Oral and Visual	COMM III.0.0	
Communication →Oral and Visual →Presentations	COMM III.A.0	Students are tasked individually or in groups with an oral presentation over a designated topic. These presentations can include visual aids such as Posters (COMM IV.A.0) or PowerPoint slides (ESTT II.D.3).
Communication →Visual	COMM IV.0.0	

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Communication →Visual →Posters	COMM IV.A.0	Students work individually or in groups to create a research poster.
Design →Engineering Design Process	DESN I.0.0	
Design →Engineering Design Process →Fundamentals of Design	DESN I.A.0	Students are groomed to follow the design process and proper procedure. This outcome is tied with DESN I.F.0 (Authentic Design) if this process is applied by students on a realistic design project.
Design →Engineering Design Process →Fundamentals of Design →Mathematical Modeling	DESN I.A.1	Students learn to use models to express a full scale design.
Design →Engineering Design Process →Fundamentals of Design →Physical Modeling	DESN I.A.2	Students learn to build scale models for a design.
Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	DESN I.A.3	Students are given a design and are tasked to evaluate its effectiveness and possible areas of improvement. Students are introduced to a proper design process such as the five step process: understand, observe, visualize, evaluate and refine.
Design →Engineering Design Process →Fundamentals of Design →Brainstorming	DESN I.A.4	Giving students a session to throw out ideas for solutions to a problem without judgment.
Design →Engineering Design Process →Fundamentals of Design →Concept Selection	DESN I.A.5	Students learn how pick the proper solution based on feasibility, criteria, constraints, etc.
Design →Engineering Design Process →Fundamentals of Design →Testing Hypothesis	DESN I.A.6	Students formulize a hypothesis and then test it empirically.
Design →Engineering Design Process →Fundamentals of Design →Design Review	DESN I.A.7	Students are given a design and are tasked to evaluate its effectiveness and identify possible areas of improvement.
Design →Engineering Design Process →Fundamentals of Design →Refine	DESN I.A.8	Based on responses from the instructor or other groups, students refine their design.
Design →Engineering Design Process →Reverse Engineering	DESN I.B.0	Students are taught the fundamentals and benefits behind the idea of reverse engineering.
Design →Engineering Design Process →Research	DESN I.C.0	Students are taught the fundamentals of conducting research for a design. This outcome is tied with the outcome set PROF IV.0.0 (Research) if methods of research are taught.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Design →Engineering Design Process →Research →User Testing	DESN I.C.1	Students test their design using appropriate methods and procedures.
Design →Engineering Design Process →Creativity and Curiosity	DESN I.D.0	The idea that student creativity fuels design is fostered in the classroom.
Design →Engineering Design Process →Empirical Design	DESN I.E.0	Students are tasked to design based upon experience or observation alone, without using scientific method or theory.
Design →Engineering Design Process →Authentic Design	DESN I.F.0	This outcome is tied with DESN I.A.0 (Fundamentals of Design).
Design →Engineering Design Process →Authentic Design →Engineering Feats and Failures	DESN I.F.1	An overview is given of past designs that have benefited from failure, and achievements today that were possible through engineering are discussed.
Design →Engineering Design Process →Authentic Design →Design Projects	DESN I.F.2	Students are assigned projects to guide them through the design process. An example of a project would be a Rube Goldberg machine. This outcome is tied with PROF III.0.0 (Teamwork) if students work in teams on this project.
Design →Engineering Design Process →Authentic Design →Realistic Design	DESN I.F.3	Students are given a project which, if it was a job or contract, would be implemented in the real world, rather than isolated and trivial design projects. This project would be hands-on and long term.
Design →Engineering Analysis	DESN II.0.0	
Design →Engineering Analysis →Data Collection and Statistical Analysis	DESN II.A.0	Students learn methods to obtain and store data. These sets of data are then analyzed using statistics.
Design →Problem Solving	DESN III.0.0	This outcome is tied with PROF I.A.1 (Problem Solving).
Design →Problem Solving →Problem Formulation	DESN III.A.0	Students are taken through the steps of identifying and clarifying significant problems.
Design →Criteria and Constraints	DESN IV.0.0	
Design →Criteria and Constraints →Design Trade-offs	DESN IV.A.0	Students are taught that designs will have certain limitations, and that the design cannot be perfect.
Design →Project Management	DESN V.0.0	
Design →Project Management →Documentation and Management	DESN V.A.0	This outcome is tied with PROF VI.0.0 (Leadership) and COMM II.A.2 (Documentation) if this outcome is part of a design project.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Design →Project Management →Scheduling	DESN V.B.0	Students schedule their own meetings with team members. This outcome is tied with ACAD II.A.0 (Time Management).
Design →Project Management →Verification	DESN V.C.0	Ensuring all jobs are complete for the successful completion of the project.
Design →Project Management →Quality Control	DESN V.D.0	Ensuring that items and procedures remain within a certain tolerance.
Design →Project Management →Data Management	DESN V.E.0	Students perform the administrative process by which data is acquired, validated, stored, protected, and processed.
Engineering Profession →Relevance of the Profession	ENPR I.0.0	Students are informed on how engineers benefit society and can provide a greater impact through future efforts.
Engineering Profession →Images of Engineering in Today's Society	ENPR II.0.0	Students are made aware of misconceptions about engineering and reasons why these generalizations are prominent.
Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	ENPR II.A.0	Students learn about the duties they will assume once they become engineers.
Engineering Profession →Professional Societies	ENPR III.0.0	Students are encouraged to join professional societies.
Engineering Profession →Professional Societies →Student Organizations	ENPR III.A.0	Students are encouraged to participate in the student chapter of their chosen discipline. These students are also eligible to hold leadership positions; this outcome is tied with PROF VI.0.0 (Leadership) if this is encouraged.
Engineering Profession →Types of Engineering	ENPR IV.0.0	The different areas of engineering are introduced and differentiated.
Engineering Profession →Engineering History	ENPR V.0.0	A brief history of engineering is discussed. Topics may include famous engineers, engineering failures, pivotal designs, etc.
Engineering Profession →Definition and Vocabulary	ENPR VI.0.0	Students learn basic concepts of engineering: criteria, constraints, design qualities, etc.
Engineering Profession →Definition and Vocabulary →Nature of Engineering	ENPR VI.A.0	Students are informed of the applications of engineering.
Engineering Profession →Definition and Vocabulary →Nature of Technology	ENPR VI.B.0	Students are informed of the applications of technology.
Engineering Profession →Disciplines of Engineering	ENPR VII.0.0	Students are introduced to the main disciplines of engineering: such as electrical, mechanical, and civil.
Engineering Profession →Disciplines of Engineering →Introduction to Professions	ENPR VII.A.0	Students are given an overview of what careers would be available when they graduate.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Engineering Profession →Commitment to Discipline	ENPR VIII.0.0	Analysis of the student's commitment to their specific discipline as related to their major is conducted by the student's advisor. This outcome is tied with ACAD VII.0.0 (Choice of Major) if students are guided to select a major to match academic interest.
Engineering Specific Tech/Tools →Engineering Skills	ESTT I.0.0	
Engineering Specific Tech/Tools →Engineering Skills →Electromagnetic Systems	ESTT I.A.0	Students are given an introduction to electromagnetism and applications in a system.
Engineering Specific Tech/Tools →Engineering Skills →Circuits	ESTT I.B.0	Resistance, capacitance, basic circuits, etc.
Engineering Specific Tech/Tools →Engineering Skills →Statics	ESTT I.C.0	Free body diagrams, forces, moments, structurally analyzing stationary objects.
Engineering Specific Tech/Tools →Engineering Skills →Mechanics	ESTT I.D.0	Analyzing the physics of the motion of an object.
Engineering Specific Tech/Tools →Engineering Skills →3-D Visualization	ESTT I.E.0	Picturing 2-dimensional objects in 3 dimensions.
Engineering Specific Tech/Tools →Engineering Skills →Material Balance	ESTT I.F.0	Students account for material, calculate mass flow rates of different streams entering or leaving chemical or physical processes.
Engineering Specific Tech/Tools →Engineering Skills →Thermodynamics	ESTT I.G.0	Introduction to the laws of thermodynamics, specific heat, calorimetry, applications.
Engineering Specific Tech/Tools →Engineering Skills → Sketching	ESTT I.H.0	Students learn the basics of drawing products by hand – basic drafting.
Engineering Specific Tech/Tools →Software	ESTT II.0.0	
Engineering Specific Tech/Tools →Software →Programming	ESTT II.A.0	
Engineering Specific Tech/Tools →Software →Programming →Basic Programming	ESTT II.A.1	Learn how to write programs for a computer in Basic.
Engineering Specific Tech/Tools →Software →Programming →Java	ESTT II.A.2	Learn how to write programs for a computer in Java. Implementing GUI.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Engineering Specific Tech/Tools →Software →Programming →Matlab	ESTT II.A.3	Students write programs on the computer to simulate calculations for engineering using MATLAB.
Engineering Specific Tech/Tools →Software →Programming →C++	ESTT II.A.4	Learn how to write programs for the computer in C++.
Engineering Specific Tech/Tools →Software →Programming →Labview	ESTT II.A.5	Students become familiar with the advantages of using Labview.
Engineering Specific Tech/Tools →Software →Programming and Design	ESTT II.B.0	
Engineering Specific Tech/Tools →Software →Programming and Design →Robotics	ESTT II.B.1	Basic programming, sensor use, and implementation of robots in different applications.
Engineering Specific Tech/Tools →Software →Computer Aided Design	ESTT II.C.0	
Engineering Specific Tech/Tools →Software →Computer Aided Design →Solid Works	ESTT II.C.1	Students become familiar with an online 3-dimensional computer-aided drafting tool.
Engineering Specific Tech/Tools →Software →Computer Aided Design →MathCAD	ESTT II.C.2	Students write programs on the computer to simulate calculations for engineering using MathCAD.
Engineering Specific Tech/Tools →Software →Computer Aided Design →AutoCAD	ESTT II.C.3	Students become familiar with an online 2 and 3 dimensional computer-aided drafting tool.
Engineering Specific Tech/Tools →Software →Computer Aided Design →Catia	ESTT II.C.4	Students become familiar with an online 3 dimensional computer-aided drafting tool.
Engineering Specific Tech/Tools →Software →Computer Aided Design →Arena	ESTT II.C.5	Students are introduced to discrete event simulation software.
Engineering Specific Tech/Tools →Software →Microsoft Office	ESTT II.D.0	
Engineering Specific Tech/Tools →Software →Microsoft Office →Word	ESTT II.D.1	Students become proficient with word processing software.
Engineering Specific Tech/Tools →Software →Microsoft Office →Excel	ESTT II.D.2	Students learn how to use Excel as a graphing tool and as a method for calculating repetitive and complicated computations.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Engineering Specific Tech/Tools →Software →Microsoft Office →PowerPoint	ESTT II.D.3	Students make use of PowerPoint to prepare presentations and posters.
Engineering Specific Tech/Tools →Software →Microsoft Office →Flowchart	ESTT II.D.4	Students learn how to organize thoughts, mainly before writing a program.
Engineering Specific Tech/Tools →Hardware	ESTT III.0.0	
Engineering Specific Tech/Tools →Hardware →Shop Experience	ESTT III.A.0	Students are given time to work with tools in the shop and become familiar with the manufacturing process. Safety precautions are also stressed.
Engineering Specific Tech/Tools →Hardware →Shop Experience →Training	ESTT III.A.1	An overview of how to operate the different available machines is given to the engineering student.
Engineering Specific Tech/Tools →Hardware →Shop Experience →Lathe, Milling	ESTT III.A.2	Students are trained on the lathe and mill.
Engineering Specific Tech/Tools →Hardware →Shop Experience →3-D Printing	ESTT III.A.3	Students gain experience with 3 dimensional printing.
Engineering Specific Tech/Tools →Hardware →Shop Experience →CNC	ESTT III.A.4	Students learn how to develop a program for a CNC machine to follow.
Engineering Specific Tech/Tools →Hardware →Shop Experience →Manufacturing	ESTT III.A.5	Students learn about the production of goods in industry: topics may include machines, tools, processing, and formulation.
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools	ESTT III.B.0	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Bread Boarding	ESTT III.B.1	Building electrical circuits on small programmable boards.
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Arduino Based Project	ESTT III.B.2	Students are involved in a project using a single-board microcontroller in applications.
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Basic Surveying	ESTT III.B.3	A general overview of surveying is given to students. Introduction to surveying techniques.
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	ESTT III.B.4	Students are assigned to conduct experiments in labs.
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Nanosensors	ESTT III.B.5	Basic operations of nanosensors are introduced.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Global Interest →Grand Challenges	GLIN I.0.0	General coverage of the NAE Grand Challenges is presented. This can be tied to a realistic design project DESN I.F.0 (Authentic Design).
Global Interest →Concern for Society	GLIN II.0.0	
Global Interest →Concern for Society →Assistive Technologies	GLIN II.A.0	Students explore the feasibility of aiding the disabled through the improvement of devices such as hearing aids, robotic wheel chairs, heart monitors, etc. (Ability One Challenge)
Global Interest →Concern for Society →Social Entrepreneurship	GLIN II.B.0	By instilling an entrepreneurial mindset, students understand their ability to impact society as an engineer.
Global Interest →Concern for Society →Design Safety	GLIN II.C.0	Students (learn how to apply / use) the design process to reduce the risk of injury to users. An example of safety engineering would be decreasing the likelihood of injury in an automobile accident.
Global Interest →Concern for Society →Sustainability	GLIN II.D.0	Students learn about the importance of designing to endure the test of time.
Global Interest →Biomechanics	GLIN III.0.0	Students study the structure and function of biological systems by the methods of mechanics.
Global Interest →Bioinformatics	GLIN IV.0.0	Students explore methods for storing, retrieving, organizing and analyzing biological data. Also, students learn to develop software tools to generate useful biological knowledge.
Global Interest →Virtual Reality	GLIN V.0.0	By increasing the interactivity and expansiveness of virtual reality, students value the applications of such technology beyond entertainment.
Global Interest →Geotechnical Engineering	GLIN VI.0.0	Introduce students to geotechnical engineering, which is concerned with the engineering behavior of earth materials. Students gain an appreciation for its applications in the military, mining, petroleum, or any other engineering concerned with construction.
Math Skills and Applications →Trig Review	MATH I.0.0	Trigonometric functions, trigonometric identities, right triangle trigonometry, law of sines, law of cosines.
Math Skills and Applications →Calculus	MATH II.0.0	Differentiation, integration, applications to engineering (i.e. acceleration, velocity), optimization.
Math Skills and Applications →Significant Figures	MATH III.0.0	Students are instructed to know when digits are significant in calculations and lab results.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Math Skills and Applications →Units and Dimensions	MATH IV.0.0	Important units (mass, volume, energy, capacitance, resistance, forces, etc.), proper use of dimensions.
Math Skills and Applications →Dimensional Analysis	MATH V.0.0	Techniques of converting units.
Math Skills and Applications →Linear Regression	MATH VI.0.0	Students are given an approach to modeling the relationship between a scalar dependent variable and one or more explanatory variables.
Math Skills and Applications →Matrices	MATH VII.0.0	Basic operations of matrices are introduced.
Math Skills and Applications →Abstraction	MATH VIII.0.0	Students are introduced to the concept of reducing the content of a concept or an observable phenomenon to retain only information which is relevant for a particular purpose.
Math Skills and Applications →Calculations	MATH IX.0.0	
Math Skills and Applications →Calculations →Statistics	MATH IX.A.0	Students are given an introduction to statistics: probability, normal curve, standard deviation, tolerances, etc.
Math Skills and Applications →Calculations →Statistics →Empirical Functions	MATH IX.A.1	The empirical distribution function is introduced to students. The cumulative distribution function is associated with the empirical measure of a sample.
Math Skills and Applications →Calculations →Graphing	MATH IX.B.0	Students are taught techniques of graphing using a table, algebra, and calculus.
Math Skills and Applications →Calculations →Estimation	MATH IX.C.0	Students are introduced to the process of finding an approximation for some purpose even if input data may be incomplete, uncertain, or unstable.
Latent Curriculum/Professional Skills →Critical Thinking	PROF I.0.0	Activating the higher pathways of thinking to solve open ended problems.
Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving	PROF I.A.0	Enhancing student abilities to analyze and solve complex problems. This outcome is tied with DESN III.0.0 (Problem Solving).
Latent Curriculum/Professional Skills →Ethics	PROF II.0.0	Students are introduced to the morals, unspoken, and spoken laws of the profession.
Latent Curriculum/Professional Skills →Ethics →Codes and Standards	PROF II.A.0	Students are made aware of the guidelines and rules that products and engineers are held to.
Latent Curriculum/Professional Skills →Teamwork	PROF III.0.0	
Latent Curriculum/Professional Skills →Teamwork →Team Management	PROF III.A.0	Students are split in teams and are taught the stages of team formation and communication.

Appendix A continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Definition
Latent Curriculum/Professional Skills →Teamwork →Team Management →Work Distribution	PROF III.A.1	Students learn how to divide the workload of a project evenly between members of a group.
Latent Curriculum/Professional Skills →Teamwork →Team Management →Strength/Weakness ID	PROF III.A.2	Identifying the assets and detriments of each member and emphasizing their positive attributes.
Latent Curriculum/Professional Skills →Teamwork →Team Dynamics	PROF III.B.0	Students realize how to work together as a team to achieve a common goal.
Latent Curriculum/Professional Skills →Research	PROF IV.0.0	Students are taught proper procedure of gathering material for a project.
Latent Curriculum/Professional Skills →Research →Library Resources	PROF IV.A.0	Students are instructed to make use of the campus library.
Latent Curriculum/Professional Skills →Research →Qualitative	PROF IV.B.0	Conducting research of information that is not easily quantified.
Latent Curriculum/Professional Skills →Research →Quantitative	PROF IV.C.0	Conducting research that is quantifiable.
Latent Curriculum/Professional Skills →Patent Search	PROF V.0.0	Students are given the basic knowledge on how to obtain a patent.
Latent Curriculum/Professional Skills →Leadership	PROF VI.0.0	Students are encouraged to take on positions involving leadership to some degree.
Latent Curriculum/Professional Skills →Entrepreneurship	PROF VII.0.0	The entrepreneurial mindset is encouraged in students.

Source: “Classification Scheme for First Year Engineering Courses,” by K. J. Reid, D. Reeping, and L. Spingola, 2013, Retrieved September 27, 2013, from http://www2.onu.edu/~k-reid/nsf/index.html

Appendix B A Revised First-Year Engineering Course Classification Scheme

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Academic Advising →Community	ACAD I.0.0	Bond with the program/department/university; collaborative learning environment; community; connection with transfer students; diversity; integration/transition into the XXX program; interactions with peer mentors/upper division students/alumni/faculty/staff/practicing engineers/industrial partners; interpersonal communication; student clubs; support groups; transition from high school to college	
Academic Advising →Community →Relationships and Friendships	ACAD I.A.0	Collaborative learning; relationships with classmates/team members	
Academic Advising →Personal Management	ACAD II.0.0	Individual challenges presented by college life; personal skills; personal success strategies	
Academic Advising →Personal Management →Time Management	ACAD II.A.0	Manage workload; work-life balance	If time management involves team meeting, then check DESN V.B.0 too
Academic Advising →Personal Management →Stress Management	ACAD II.B.0	Relieve stress	
Academic Advising →E-Portfolio Design	ACAD III.0.0	Career development/guidance/planning/preparation; career service center; career success skills/strategies; career-related issues; prepare applications	Same as COMM II.C.0
Academic Advising →Academic Integrity	ACAD IV.0.0	Academic integrity	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Academic Advising →Advising	ACAD V.0.0	Academic and non-academic activities including extra-curricular activities; academic challengies/expectations/goals/issues/motivation/policies/preparation; career objectives; cognitive/skill development; diversity; information literacy; integration of students into the program; learning methods; success skills; transition from high school to college life	
Academic Advising →Advising →Plan of Study	ACAD V.A.0	Academic/educational objectives; class scheduling; curriculum; post-baccalaureate education	
Academic Advising →Advising →Study Abroad	ACAD V.B.0	Study abroad	
Academic Advising →Advising →Co-op or Internship	ACAD V.C.0	Career planning/preparation; career service center; career success skills/strategies; career-related issues; co-op; internship; job searches; prepare applications	ACAD V.C.0 includes ACAD III.0.0 (COMM II.C.0)
Academic Advising →Advising →Co-op or Internship →Interviews	ACAD V.C.1	Interview skills	
Academic Advising →Advising →Introduction to Campus	ACAD V.D.0	University life; university culture/facilities/organization/policies/procedures/programs/resources/services/structure/traditions;	
Academic Advising →Advising →Introduction to Departments	ACAD V.E.0	College/department facilities/policies/programs/resources/services; degree requirements; faculty members/staff; research areas of faculty members	
Academic Advising →Advising →Undergraduate Research	ACAD V.F.0	Research opportunities; undergraduate research	
Academic Advising →Lifelong Learning	ACAD VI.0.0	Continuing education; lifelong learning	
Academic Advising →Choice of Major	ACAD VII.0.0	Academic interest; choose/select a major; selection of an engineering major field	
Communication →Professional	COMM I.0.0		

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Communication →Professional →Client Interactions	COMM I.A.0	Client-centered	
Communication →Written	COMM II.0.0	(Professional/Technical) communication; content; date display/presentation; format; grammar; style; written expression skills	
Communication →Written →Reports	COMM II.A.0	Present results professionally; report format; technical communication/writing	
Communication →Written →Reports →Lab	COMM II.A.1	Lab report/writing	
Communication →Written →Reports →Documentation	COMM II.A.2	Documentation; logbook; memo; workbook	Same as DESN V.A.0
Communication →Written →Reports →Engineering	COMM II.A.3	Project proposal; technical/written report	
Communication →Written →Email Writing	COMM II.B.0	E-mail; writing of letters	
Communication →Written →Resume	COMM II.C.0	Same as ACAD III.0.0	Same as ACAD III.0.0
Communication →Oral and Visual	COMM III.0.0	(Professional/Technical) communication; date display/presentation; oral report/skill; present results professionally; meeting/speaking skills	
Communication →Oral and Visual →Presentations	COMM III.A.0	Presentation skills	
Communication →Visual	COMM IV.0.0	Graphic communication; visualization	
Communication →Visual →Posters	COMM IV.A.0	Poster	
Design →Engineering Design Process	DESN I.0.0	Design; design issues/methods/problems/resources/skills/strategies/techniques; design for XXX; XXX design; decision making/process	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Design →Engineering Design Process →Fundamentals of Design	DESN I.A.0	Aesthetic/component/functional/rational design; an understanding of engineering design; bill of materials; design assumptions; design challenges/concepts/philosophy/principles/theory; the role/scope of design; top-down design	Emphasize basic design/design-related concepts, as compared to DESN I.A.3
Design →Engineering Design Process →Fundamentals of Design →Mathematical Modeling	DESN I.A.1	Computational/computer/numerical/system modeling; modeling; modeling methods/techniques	
Design →Engineering Design Process →Fundamentals of Design →Physical Modeling	DESN I.A.2	Modeling; modeling methods/techniques; (physical) prototype; (rapid) prototyping	
Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	DESN I.A.3	A series of design steps such as devise, evaluate, and defend a solution to a design problem; construction; design cycle/patterns/phases/procedures/stages/steps; (re)definition the design goals/objectives; implementation; interpretation of results; performance prediction	Emphasize action, as compared to DESN I.A.0
Design →Engineering Design Process →Fundamentals of Design →Brainstorming	DESN I.A.4	Brainstorming	
Design →Engineering Design Process →Fundamentals of Design →Concept Selection	DESN I.A.5	Analysis/Comparison of alternatives; feasible solutions; select the best alternative	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Design →Engineering Design Process →Fundamentals of Design →Testing Hypothesis	DESN I.A.6	Debug; test; validate; verification	Test based on experience or observation without using scientific method/theory, as compared to DESN I.C.1
Design →Engineering Design Process →Fundamentals of Design →Design Review	DESN I.A.7	An appreciation for good design; assessment; develop/explore alternatives; evaluation	
Design →Engineering Design Process →Fundamentals of Design →Refine	DESN I.A.8	Peer review; redesign	
Design →Engineering Design Process →Reverse Engineering	DESN I.B.0	Reverse engineering	
Design →Engineering Design Process →Research	DESN I.C.0	Research; research fundamental concepts such as literature, journals, publications; research processes such as argument development, use of resources, citation	DESN I.C.0 includes PROF IV.0.0 (DESN I.C.0 includes both research concepts and research methods, while PROF IV.0.0 emphasize research methods)

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Design →Engineering Design Process →Research →User Testing	DESN I.C.1	Circuit/programming/software testing; debug; troubleshoot; validate; verification	Test using appropriate methods and procedures, as compared to DESN I.A.6
Design →Engineering Design Process →Creativity and Curiosity	DESN I.D.0	Creative design/thinking; creative problem solving; exploration; imagination skills; innovation; invention/inventiveness	
Design →Engineering Design Process →Empirical Design	DESN I.E.0	Conceptual design; design activity/construction/practice	
Design →Engineering Design Process →Authentic Design	DESN I.F.0	Design activity/construction/practice	
Design →Engineering Design Process →Authentic Design →Engineering Feats and Failures	DESN I.F.1	Study disasters/failures/feats	
Design →Engineering Design Process →Authentic Design →Design Projects	DESN I.F.2	Design competition/project/task; project-based design/learning	
Design →Engineering Design Process →Authentic Design →Realistic Design	DESN I.F.3	Realistic problems	
Design →Engineering Analysis	DESN II.0.0	Analytical approaches; assessment; cost analysis/estimation; data/problem/system analysis/interpretation/evaluation/manipulation; dissection; investigation; methods for analysis; synthesis	
Design →Engineering Analysis →Data Collection and Statistical Analysis	DESN II.A.0	Data acquisition/collection/gathering; information access/gathering/retrieval; mathematical manipulation of data; statistical analysis	
Design →Problem Solving	DESN III.0.0	Approaches to problem solving; develop solutions; problem solving methods/techniques; solutions to problems	Same as PROF I.A.0

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Design →Problem Solving →Problem Formulation	DESN III.A.0	Concept/idea generation; conceptualization; need-finding; observation; problem definition/formulation/identification/requirements/specifications;	
Design →Criteria and Constraints	DESN IV.0.0	Budgetary; constraints; cost; criteria; economics; product quality; resource availability; standards; technical and aesthetic considerations	
Design →Criteria and Constraints →Design Trade-offs	DESN IV.A.0	Conflict resolution; conflicting factors	
Design →Project Management	DESN V.0.0	Project management skills/tools; project planning;	
Design →Project Management →Documentation and Management	DESN V.A.0	Same as COMM II.A.2	Same as COMM II.A.2
Design →Project Management →Scheduling	DESN V.B.0	Scheduling	If schedule for a team meeting, need to check ACAD II.A.0 too
Design →Project Management →Verification	DESN V.C.0		
Design →Project Management →Quality Control	DESN V.D.0	Accuracy and variability; quality management	
Design →Project Management →Data Management	DESN V.E.0	data acquisition/collection/gathering; data control/handling/integration/manipulation/organization/processing/ reduction/transfer; data description/maps; information access/gathering/retrieval;	
Engineering Profession →Relevance of the Profession	ENPR I.0.0	Contributions; engineering work place; impact; importance; issues/problems relevant to engineering; professional development/growth/issues; relationships with society/other disciplines	
Engineering Profession →Images of Engineering in Today's Society	ENPR II.0.0	Engineering practice issues; issues encountered in engineering; issues facing engineers; professional issues; reaction of our culture	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	ENPR II.A.0	Activities; engineer's liability/responsibility/role; expectations of the profession; functions; practices; requirements	
Engineering Profession →Professional Societies	ENPR III.0.0	Organizations; professional licensure/organization/registration/society	
Engineering Profession →Professional Societies →Student Organizations	ENPR III.A.0	Professional society student chapters; student organizations	
Engineering Profession →Types of Engineering	ENPR IV.0.0	Differences/relationships between engineering disciplines	
Engineering Profession →Engineering History	ENPR V.0.0	Achievement; development; history	ENPR V.0.0 includes DESN I.F.1
Engineering Profession →Definition and Vocabulary	ENPR VI.0.0	Concurrent engineering; engineering concepts/fundamentals/knowledge/methods/perspectives/philosophy/principles/techniques/terminology/vocabulary	
Engineering Profession →Definition and Vocabulary →Nature of Engineering	ENPR VI.A.0	Applications of engineering	
Engineering Profession →Definition and Vocabulary →Nature of Technology	ENPR VI.B.0	Applications of technology	
Engineering Profession →Disciplines of Engineering	ENPR VII.0.0	Advances/issues/themes/topics in XXX engineering; aims/goals/nature/scenarios/scope of XXX engineering; areas/specializations within XXX engineering; contemporary/current/future trends; perspective on XXX engineering; technical aspect of XXX engineering; the (sub-)field of XXX engineering; XXX discipline/engineering; XXX engineering education/research	
Engineering Profession →Disciplines of Engineering →Introduction to Professions	ENPR VII.A.0	Career; culture of the profession; opportunities; profession; topics relevant to the profession	
Engineering Profession →Commitment to Discipline	ENPR VIII.0.0	Interest in XXX engineering; understanding of the chosen field	
Engineering Specific Tech/Tools →Engineering Skills	ESTT I.0.0		

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Engineering Specific Tech/Tools →Engineering Skills →Electromagnetic Systems	ESTT I.A.0	Electromagnetic fields; electromagnetics; electromagnetism	
Engineering Specific Tech/Tools →Engineering Skills →Circuits	ESTT I.B.0	AC and DC circuits; analog circuits; arithmetic and logic circuits; combinational and sequential circuits; integrated circuits; Kirchhoff's laws; series and parallel circuits; Thevenin and Norton equivalent circuits	
Engineering Specific Tech/Tools →Engineering Skills →Statics	ESTT I.C.0	Statics; vector statics; related concepts such as center of gravity, centroid, couples, force systems and equilibrium, frames, friction, machine, moments of inertia for areas, Newtonian mechanics of force systems, rigid bodies, trusses, two and three dimensional equilibrium of particles, vector algebra	
Engineering Specific Tech/Tools →Engineering Skills →Mechanics	ESTT I.D.0	Dynamics; fluid mechanics; related concepts such as controls, Coulomb friction, couples, distributed forces, equivalent force-couple systems, forces, moments, vector mechanics	
Engineering Specific Tech/Tools →Engineering Skills →Graphics	**ESTT I.E.0**	**Assembly/detail drawing; auxiliary views; blueprint reading; charts; dimensioning; drafting; drawing; drawing standards; geometric construction; graphics; isometric projection; lettering; modeling; multi-view drawing; orthographic projection; pictorial drawings; sectioning; solid modeling; tolerancing**	
Engineering Specific Tech/Tools →Engineering Skills →Graphics →3-D Visualization	**ESTT I.E.1**	2-D and 3-D drafting/drawings/modeling/thinking/visualization	
Engineering Specific Tech/Tools →Engineering Skills →Graphics →Sketching	**ESTT I.E.2**	Conventional drawing; drawing instruments; freehand sketching; manual drafting/drawing; sketching	
Engineering Specific Tech/Tools →Engineering Skills →Material Balance	ESTT I.F.0	Chemical process; material and energy balances	
Engineering Specific Tech/Tools →Engineering Skills →Thermodynamics	ESTT I.G.0	Heat and mass transfer	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Engineering Specific Tech/Tools →Engineering Skills →Material Property and Structure	**ESTT I.H.0**	**Concepts related to property and structure of materials, such as stress and strain, compression and tension**	
Engineering Specific Tech/Tools →Engineering Skills →Engineering Science	**ESTT I.I.0**	**Biology, chemistry, geography, geology, physics, etc.**	
Engineering Specific Tech/Tools →Software	ESTT II.0.0	Computational/computer modeling; computation; computer applications; computer as a tool; computing; database; network; presentation software; simulation; software; spreadsheet; web development	
Engineering Specific Tech/Tools →Software →Programming	ESTT II.A.0	Computation; programming related concepts	
Engineering Specific Tech/Tools →Software →Programming →Basic Programming	ESTT II.A.1	Visual Basic	
Engineering Specific Tech/Tools →Software →Programming →Java	ESTT II.A.2	Java	
Engineering Specific Tech/Tools →Software →Programming →Matlab	ESTT II.A.3	Matlab	
Engineering Specific Tech/Tools →Software →Programming →**C and** C++	ESTT II.A.4	**C;** C++	
Engineering Specific Tech/Tools →Software →Programming →Labview	ESTT II.A.5	Labview	
Engineering Specific Tech/Tools →Software →Programming and Design	ESTT II.B.0		
Engineering Specific Tech/Tools →Software →Programming and Design →Robotics	ESTT II.B.1	Robotics and related concepts	
Engineering Specific Tech/Tools →Software →Computer Aided Design	ESTT II.C.0	CAD commands and functions; computer graphics; rapid prototyping	
Engineering Specific Tech/Tools →Software →Computer Aided Design →Solid Works	ESTT II.C.1	SolidWorks	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Engineering Specific Tech/Tools →Software →Computer Aided Design →MathCAD	ESTT II.C.2	MathCAD	
Engineering Specific Tech/Tools →Software →Computer Aided Design →AutoCAD	ESTT II.C.3	AutoCAD	
Engineering Specific Tech/Tools →Software →Computer Aided Design →Catia	ESTT II.C.4	Catia	
Engineering Specific Tech/Tools →Software →Computer Aided Design →Arena	ESTT II.C.5	Arena	
Engineering Specific Tech/Tools →Software →Microsoft Office	ESTT II.D.0	Office	
Engineering Specific Tech/Tools →Software →Microsoft Office →Word	ESTT II.D.1	Word	
Engineering Specific Tech/Tools →Software →Microsoft Office →Excel	ESTT II.D.2	Excel; spreadsheet	
Engineering Specific Tech/Tools →Software →Microsoft Office →PowerPoint	ESTT II.D.3	PowerPoint; presentation software	
Engineering Specific Tech/Tools →Software →Microsoft Office →Flowchart	ESTT II.D.4	Flowchart	
Engineering Specific Tech/Tools →Hardware	ESTT III.0.0	Hardware; (design/engineering) tools	
Engineering Specific Tech/Tools →Hardware →Shop Experience	ESTT III.A.0	Field trip; machine shop; tour; visit	
Engineering Specific Tech/Tools →Hardware →Shop Experience →Training	ESTT III.A.1	Equipment; operation of the instruments, machines, and tools; plant operation; shipboard training; training	
Engineering Specific Tech/Tools →Hardware →Shop Experience →Lathe, Milling	ESTT III.A.2	Introduction to the usage of lathe and mill; lathe; mill	
Engineering Specific Tech/Tools →Hardware →Shop Experience →3-D Printing	ESTT III.A.3		
Engineering Specific Tech/Tools →Hardware →Shop Experience →CNC	ESTT III.A.4	(Computer) numerical control	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Engineering Specific Tech/Tools →Hardware →Shop Experience →Manufacturing	ESTT III.A.5	Casting; cutting; deformation processes; drilling; fabrication; forming; joining processes; measurement tools and procedures; milling; molding; packaging; polymer processes; product realization; sawing; turning; welding	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools	ESTT III.B.0		
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Bread Boarding	ESTT III.B.1	Bread board; circuit assembly/implementation; circuit board	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Arduino Based Project	ESTT III.B.2	Microcontroller	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Basic Surveying	ESTT III.B.3	GIS; GPS; survey and related concepts including field equipment	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	ESTT III.B.4	Lab	
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Nanosensors	ESTT III.B.5		
Global Interest →Grand Challenges	GLIN I.0.0	Challenges and opportunities; globalization	
Global Interest →Concern for Society	GLIN II.0.0	Cultural issues; global issues; human factors; political aspects; social concerns	
Global Interest →Concern for Society →Assistive Technologies	GLIN II.A.0	Rehabilitation engineering	
Global Interest →Concern for Society →Social Entrepreneurship	GLIN II.B.0	Entrepreneurial mindset; entrepreneurship	
Global Interest →Concern for Society →Design Safety	GLIN II.C.0	Safety issues	
Global Interest →Concern for Society →Sustainability	GLIN II.D.0	Energy and alternate energy; environment; green environment; sustainability; sustainable development	
Global Interest →Biomechanics	GLIN III.0.0	Biomechanics	
Global Interest →Bioinformatics	GLIN IV.0.0	Bioinformatics	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Global Interest →Virtual Reality	GLIN V.0.0		
Global Interest →Geotechnical Engineering	GLIN VI.0.0	Geotechnics	
Math Skills and Applications →Trig Review	MATH I.0.0	Frequency and phase; parametric equations; sinusoids; trigonometry	
Math Skills and Applications →Calculus	MATH II.0.0	Differentiation; integration; pre-calculus; vector calculus	
Math Skills and Applications →Significant Figures **and Measurement**	MATH III.0.0	**Accuracy; error; error analysis; measurement; precision; variability**	
Math Skills and Applications →Units and Dimensions	MATH IV.0.0	Dimensions; units	
Math Skills and Applications →Dimensional Analysis	MATH V.0.0	Conversions; dimensional analysis	
Math Skills and Applications →Linear Regression	MATH VI.0.0	Correlations; linear/multiple regression; regression	
Math Skills and Applications →Matrices	MATH VII.0.0	Matrix algebra; matrix method; vector	
Math Skills and Applications →Abstraction	MATH VIII.0.0	Abstraction; data/procedural abstraction	
Math Skills and Applications →Calculations	MATH IX.0.0	Algebra; mathematical operations	
Math Skills and Applications →Calculations →Statistics	MATH IX.A.0	Analysis of variance; confidence intervals; density functions; deterministic and stochastic systems; hypothesis testing; random variables; regression analysis	
Math Skills and Applications →Calculations →Statistics →Empirical Functions	MATH IX.A.1	Distribution functions	
Math Skills and Applications →Calculations →Graphing	MATH IX.B.0	Graph Theory; graphical analysis; graphing; graphs; polar coordinates; vector; vector algebra	
Math Skills and Applications →Calculations →Estimation	MATH IX.C.0	Approximation; computation; curve fitting; dynamic programming; estimation; heuristic approaches; interpolation; least squares fitting; linear programming; numerical analysis/methods/techniques; numerical integration and differentiation; root finding; solution of linear and nonlinear equations	
Math Skills and Applications →Geometry	**MATH X.0.0**	**Cartesian coordinates; descriptive geometry; intersection; line; plane; point; revolution**	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Math Skills and Applications →Others	**MATH XI.0.0**	**General mathematics and other math topics not included in the above topics such as complex numbers, discrete mathematics, mathematical analysis, and topology**	
Latent Curriculum/Professional Skills →Critical Thinking	PROF I.0.0	Critical thinking	
Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving	PROF I.A.0	Same as DESN III.0.0	Same as DESN III.0.0
Latent Curriculum/Professional Skills →Ethics	PROF II.0.0	Behavioral/moral issues; contracts; ethical and professional responsibilities; law; privacy; professionalism; professional behavior/conduct/expectations; regulation; social protocol	
Latent Curriculum/Professional Skills →Ethics →Codes and Standards	PROF II.A.0	Codes; conventions; obligations; professional standards	
Latent Curriculum/Professional Skills →Teamwork	PROF III.0.0	Collaboration; collaborative work; group; group activity/discussion/work; teamwork	
Latent Curriculum/Professional Skills →Teamwork →Team Management	PROF III.A.0	Team building/development	
Latent Curriculum/Professional Skills →Teamwork →Team Management →Work Distribution	PROF III.A.1		
Latent Curriculum/Professional Skills →Teamwork →Team Management →Strength/Weakness ID	PROF III.A.2		
Latent Curriculum/Professional Skills →Teamwork →Team Dynamics	PROF III.B.0	Team dynamics	
Latent Curriculum/Professional Skills →Research	PROF IV.0.0	Collect and incorporate materials; develop/support arguments; information search; research; research methods/procedures/process; use of resources	
Latent Curriculum/Professional Skills →Research →Library Resources	PROF IV.A.0	Information; internet; library; literature; resources	
Latent Curriculum/Professional Skills →Research →Qualitative	PROF IV.B.0	Qualitative methods	

Appendix B continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequently Appearing Keyword	Note
Latent Curriculum/Professional Skills →Research →Quantitative	PROF IV.C.0	Quantitative methods	
Latent Curriculum/Professional Skills →Patent Search	PROF V.0.0	Intellectual property; patent application and search	
Latent Curriculum/Professional Skills →Leadership	PROF VI.0.0	Leadership	
Latent Curriculum/Professional Skills →Entrepreneurship	PROF VII.0.0	Entrepreneurship	

Appendix C Frequency of Categories Listed in First-Year Engineering Course Descriptions per Course (Number of Courses = 2,222)

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Profession →Definition and Vocabulary	ENPR VI.0.0	658	29.61%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	ESTT III.B.4	596	26.82%
Engineering Specific Tech/Tools →Software	ESTT II.0.0	552	24.84%
Design →Problem Solving (Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving)	DESN III.0.0 (PROF I.A.0)	508	22.86%
Engineering Profession →Disciplines of Engineering	ENPR VII.0.0	481	21.65%
Engineering Specific Tech/Tools →Software →Programming	ESTT II.A.0	433	19.49%
Design →Engineering Design Process	DESN I.0.0	401	18.05%
Engineering Specific Tech/Tools →Software →Computer Aided Design	ESTT II.C.0	399	17.96%
Engineering Profession →Disciplines of Engineering →Introduction to Professions	ENPR VII.A.0	371	16.70%
Design →Engineering Design Process →Authentic Design →Design Projects	DESN I.F.2	366	16.47%
Engineering Specific Tech/Tools →Engineering Skills →Graphics	ESTT I.E.0	340	15.30%
Latent Curriculum/Professional Skills →Teamwork	PROF III.0.0	328	14.76%
Design →Engineering Analysis	DESN II.0.0	305	13.73%
Latent Curriculum/Professional Skills →Ethics	PROF II.0.0	298	13.41%
Communication →Written	COMM II.0.0	225	10.13%
Engineering Specific Tech/Tools →Engineering Skills →Circuits	ESTT I.B.0	196	8.82%
Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	DESN I.A.3	195	8.78%
Math Skills and Applications →Calculations →Estimation	MATH IX.C.0	166	7.47%
Academic Advising →Advising	ACAD V.0.0	165	7.43%
Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	ENPR II.A.0	154	6.93%
Communication →Oral and Visual	COMM III.0.0	140	6.30%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Specific Tech/Tools →Engineering Skills →Sketching	ESTT I.E.2	135	6.08%
Engineering Specific Tech/Tools →Software →Microsoft Office →Excel	ESTT II.D.2	130	5.85%
Academic Advising →Advising →Introduction to Departments	ACAD V.E.0	128	5.76%
Engineering Profession →Relevance of the Profession	ENPR I.0.0	122	5.49%
Communication →Oral and Visual →Presentations	COMM III.A.0	111	5.00%
Engineering Specific Tech/Tools →Software →Programming →Matlab	ESTT II.A.3	105	4.73%
Engineering Specific Tech/Tools →Engineering Skills →3-D Visualization	ESTT I.E.1	100	4.50%
Engineering Specific Tech/Tools →Engineering Skills →Statics	ESTT I.C.0	89	4.01%
Engineering Profession →Engineering History	ENPR V.0.0	87	3.92%
Engineering Specific Tech/Tools →Software →Programming →C++	ESTT II.A.4	87	3.92%
Academic Advising →Advising →Plan of Study	ACAD V.A.0	83	3.74%
Engineering Specific Tech/Tools →Engineering Skills →Material Property and Structure	ESTT I.H.0	82	3.69%
Academic Advising →Advising →Introduction to Campus	ACAD V.D.0	79	3.56%
Communication →Written →Reports	COMM II.A.0	77	3.47%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Manufacturing	ESTT III.A.5	77	3.47%
Math Skills and Applications →Calculations →Graphing	MATH IX.B.0	76	3.42%
Engineering Specific Tech/Tools →Engineering Skills →Engineering Science	ESTT I.I.0	74	3.33%
Design →Engineering Design Process →Creativity and Curiosity	DESN I.D.0	71	3.20%
Academic Advising →Community	ACAD I.0.0	70	3.15%
Engineering Specific Tech/Tools →Hardware →Shop Experience	ESTT III.A.0	69	3.11%
Math Skills and Applications →Geometry	MATH X.0.0	69	3.11%
Design →Criteria and Constraints	DESN IV.0.0	68	3.06%
Latent Curriculum/Professional Skills →Ethics →Codes and Standards	PROF II.A.0	66	2.97%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Basic Surveying	ESTT III.B.3	63	2.84%
Engineering Profession →Definition and Vocabulary →Nature of Engineering	ENPR VI.A.0	60	2.70%
Design →Problem Solving →Problem Formulation	DESN III.A.0	57	2.57%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Specific Tech/Tools →Engineering Skills →Mechanics	ESTT I.D.0	56	2.52%
Design →Engineering Design Process →Fundamentals of Design	DESN I.A.0	54	2.43%
Engineering Specific Tech/Tools →Hardware	ESTT III.0.0	54	2.43%
Math Skills and Applications →Other Topics	MATH XI.0.0	52	2.34%
Academic Advising →Advising →Co-op or Internship	ACAD V.C.0	51	2.30%
Design →Engineering Analysis →Data Collection and Statistical Analysis	DESN II.A.0	49	2.21%
Engineering Profession →Professional Societies	ENPR III.0.0	48	2.16%
Communication →Written →Reports →Documentation (Design →Project Management →Documentation and Management)	COMM II.A.2 (DESN V.A.0)	47	2.12%
Design →Project Management	DESN V.0.0	47	2.12%
Global Interest →Concern for Society	GLIN II.0.0	47	2.12%
Global Interest →Concern for Society →Design Safety	GLIN II.C.0	45	2.03%
Design →Engineering Design Process →Fundamentals of Design →Mathematical Modeling	DESN I.A.1	43	1.94%
Global Interest →Concern for Society →Sustainability	GLIN II.D.0	43	1.94%
Math Skills and Applications →Calculus	MATH II.0.0	43	1.94%
Design →Engineering Design Process →Fundamentals of Design →Physical Modeling	DESN I.A.2	42	1.89%
Engineering Specific Tech/Tools →Software →Computer Aided Design →AutoCAD	ESTT II.C.3	42	1.89%
Design →Engineering Design Process →Research	DESN I.C.0	39	1.76%
Math Skills and Applications →Calculations →Statistics	MATH IX.A.0	39	1.76%
Design →Project Management →Data Management	DESN V.E.0	38	1.71%
Engineering Specific Tech/Tools →Software →Microsoft Office →Word	ESTT II.D.1	38	1.71%
Latent Curriculum/Professional Skills →Research →Library Resources	PROF IV.A.0	36	1.62%
Design →Engineering Design Process →Research →User testing	DESN I.C.1	35	1.58%
Academic Advising →E-Portfolio Design (Communication →Written →Resume)	ACAD III.0.0 (COMM II.C.0)	34	1.53%
Math Skills and Applications →Calculations	MATH IX.0.0	34	1.53%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Communication →Visual	COMM IV.0.0	32	1.44%
Communication →Written →Reports →Engineering	COMM II.A.3	31	1.40%
Math Skills and Applications →Significant Figures and Measurement	MATH III.0.0	31	1.40%
Design →Engineering Design Process →Fundamentals of Design →Testing Hypothesis	DESN I.A.6	29	1.31%
Latent Curriculum/Professional Skills →Critical Thinking	PROF I.0.0	29	1.31%
Latent Curriculum/Professional Skills →Research	PROF IV.0.0	28	1.26%
Design →Engineering Design Process →Empirical Design	DESN I.E.0	27	1.22%
Math Skills and Applications →Matrices	MATH VII.0.0	26	1.17%
Academic Advising →Personal Management →Time Management	ACAD II.A.0	25	1.13%
Math Skills and Applications →Units and Dimensions	MATH IV.0.0	25	1.13%
Engineering Specific Tech/Tools →Engineering Skills →Thermodynamics	ESTT I.G.0	23	1.04%
Design →Engineering Design Process →Fundamentals of Design →Design Review	DESN I.A.7	22	0.99%
Engineering Specific Tech/Tools →Engineering Skills →Material Balance	ESTT I.F.0	22	0.99%
Engineering Specific Tech/Tools →Software →Programming and Design →Robotics	ESTT II.B.1	21	0.95%
Academic Advising →Lifelong Learning	ACAD VI.0.0	20	0.90%
Engineering Profession →Types of Engineering	ENPR IV.0.0	19	0.86%
Engineering Specific Tech/Tools →Software →Microsoft Office →PowerPoint	ESTT II.D.3	19	0.86%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Training	ESTT III.A.1	19	0.86%
Global Interest →Grand Challenges	GLIN I.0.0	19	0.86%
Math Skills and Applications →Dimensional Analysis	MATH V.0.0	19	0.86%
Design →Engineering Design Process →Authentic Design	DESN I.F.0	17	0.77%
Engineering Specific Tech/Tools →Software →Microsoft Office →Flowchart	ESTT II.D.4	17	0.77%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Bread boarding	ESTT III.B.1	17	0.77%
Engineering Specific Tech/Tools →Software →Programming →Basic Programming	ESTT II.A.1	16	0.72%
Academic Advising →Choice of Major	ACAD VII.0.0	14	0.63%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Solid Works	ESTT II.C.1	14	0.63%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Math Skills and Applications →Abstraction	MATH VIII.0.0	14	0.63%
Latent Curriculum/Professional Skills →Teamwork →Team Management	PROF III.A.0	14	0.63%
Design →Engineering Design Process →Fundamentals of Design →Concept Selection	DESN I.A.5	13	0.59%
Engineering Profession →Images of Engineering in Today's Society	ENPR II.0.0	13	0.59%
Engineering Profession →Professional Societies →Student Organizations	ENPR III.A.0	13	0.59%
Latent Curriculum/Professional Skills →Patent Search	PROF V.0.0	13	0.59%
Design →Project Management →Quality Control	DESN V.D.0	12	0.54%
Engineering Specific Tech/Tools →Software →Programming →Java	ESTT II.A.2	12	0.54%
Engineering Specific Tech/Tools →Software →Microsoft Office	ESTT II.D.0	12	0.54%
Engineering Specific Tech/Tools →Hardware →Shop Experience →CNC	ESTT III.A.4	12	0.54%
Latent Curriculum/Professional Skills →Entrepreneurship	PROF VII.0.0	12	0.54%
Design →Engineering Design Process →Reverse Engineering	DESN I.B.0	11	0.50%
Engineering Specific Tech/Tools →Engineering Skills →Electromagnetic Systems	ESTT I.A.0	11	0.50%
Engineering Specific Tech/Tools →Software →Computer Aided Design →MathCAD	ESTT II.C.2	10	0.45%
Communication →Written →Reports →Lab	COMM II.A.1	9	0.41%
Engineering Profession →Definition and Vocabulary →Nature of Technology	ENPR VI.B.0	9	0.41%
Engineering Specific Tech/Tools →Software →Programming →Labview	ESTT II.A.5	9	0.41%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Lathe, Milling	ESTT III.A.2	9	0.41%
Design →Project Management →Scheduling	DESN V.B.0	8	0.36%
Engineering Profession →Commitment to Discipline	ENPR VIII.0.0	8	0.36%
Global Interest →Geotechnical Engineering	GLIN VI.0.0	8	0.36%
Academic Advising →Personal Management	ACAD II.0.0	7	0.32%
Academic Advising →Advising →Undergraduate Research	ACAD V.F.0	7	0.32%
Math Skills and Applications →Trig Review	MATH I.0.0	7	0.32%
Latent Curriculum/Professional Skills →Teamwork →Team Dynamics	PROF III.B.0	7	0.32%
Academic Advising →Community →Relationships and Friendships	ACAD I.A.0	6	0.27%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Design →Engineering Design Process →Authentic Design →Realistic Design	DESN I.F.3	6	0.27%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Arduino Based Project	ESTT III.B.2	6	0.27%
Design →Engineering Design Process →Fundamentals of Design →Refine	DESN I.A.8	5	0.23%
Design →Criteria and Constraints →Design Trade-offs	DESN IV.A.0	5	0.23%
Math Skills and Applications →Linear Regression	MATH VI.0.0	5	0.23%
Latent Curriculum/Professional Skills →Leadership	PROF VI.0.0	5	0.23%
Communication →Written →Email writing	COMM II.B.0	4	0.18%
Latent Curriculum/Professional Skills →Research →Quantitative	PROF IV.C.0	4	0.18%
Academic Advising →Advising →Study Abroad	ACAD V.B.0	3	0.14%
Design →Engineering Design Process →Authentic Design →Engineering Feats and Failures	DESN I.F.1	3	0.14%
Global Interest →Concern for Society →Assistive Technologies	GLIN II.A.0	3	0.14%
Global Interest →Biomechanics	GLIN III.0.0	3	0.14%
Global Interest →Bioinformatics	GLIN IV.0.0	3	0.14%
Academic Advising →Personal Management →Stress Management	ACAD II.B.0	2	0.09%
Academic Advising →Academic Integrity	ACAD IV.0.0	2	0.09%
Academic Advising →Advising →Co-op or Internship →Interviews	ACAD V.C.1	2	0.09%
Communication →Visual →Posters	COMM IV.A.0	2	0.09%
Design →Engineering Design Process →Fundamentals of Design →Brainstorming	DESN I.A.4	2	0.09%
Global Interest →Concern for Society →Social Entrepreneurship	GLIN II.B.0	2	0.09%
Math Skills and Applications →Calculations →Statistics →Empirical Functions	MATH IX.A.1	2	0.09%
Communication →Professional →Client Interactions	COMM I.A.0	1	0.05%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Arena	ESTT II.C.5	1	0.05%
Latent Curriculum/Professional Skills →Research →Qualitative	PROF IV.B.0	1	0.05%
Communication →Professional	COMM I.0.0	0	0.00%
Design →Project Management →Verification	DESN V.C.0	0	0.00%
Engineering Specific Tech/Tools →Engineering Skills	ESTT I.0.0	0	0.00%

Appendix C continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Specific Tech/Tools →Software →Programming and Design	ESTT II.B.0	0	0.00%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Catia	ESTT II.C.4	0	0.00%
Engineering Specific Tech/Tools →Hardware →Shop Experience →3-D Printing	ESTT III.A.3	0	0.00%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools	ESTT III.B.0	0	0.00%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Nanosensors	ESTT III.B.5	0	0.00%
Global Interest →Virtual Reality	GLIN V.0.0	0	0.00%
Latent Curriculum/Professional Skills →Teamwork →Team Management →Work Distribution	PROF III.A.1	0	0.00%
Latent Curriculum/Professional Skills →Teamwork →Team Management →Strength/Weakness ID	PROF III.A.2	0	0.00%

Appendix D Frequency of Categories Listed in First-Year Engineering Course Descriptions per Institution (Number of Institutions = 374)

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Design →Problem Solving (Latent Curriculum/Professional Skills →Critical Thinking →Problem Solving)	DESN III.0.0 (PROF I.A.0)	262	70.05%
Engineering Profession →Definition and Vocabulary	ENPR VI.0.0	256	68.45%
Engineering Specific Tech/Tools →Software	ESTT II.0.0	256	68.45%
Design →Engineering Design Process	DESN I.0.0	249	66.58%
Engineering Specific Tech/Tools →Software →Computer Aided Design	ESTT II.C.0	246	65.78%
Engineering Profession →Disciplines of Engineering	ENPR VII.0.0	243	64.97%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Laboratory	ESTT III.B.4	234	62.57%
Engineering Specific Tech/Tools →Software →Programming	ESTT II.A.0	231	61.76%
Engineering Specific Tech/Tools →Engineering Skills →Graphics	ESTT I.E.0	225	60.16%
Design →Engineering Design Process →Authentic Design →Design Projects	DESN I.F.2	218	58.29%
Latent Curriculum/Professional Skills →Teamwork	PROF III.0.0	213	56.95%
Engineering Profession →Disciplines of Engineering →Introduction to Professions	ENPR VII.A.0	205	54.81%
Latent Curriculum/Professional Skills →Ethics	PROF II.0.0	182	48.66%
Design →Engineering Analysis	DESN II.0.0	177	47.33%
Communication →Written	COMM II.0.0	163	43.58%
Design →Engineering Design Process →Fundamentals of Design →Formal Design Process	DESN I.A.3	146	39.04%
Engineering Specific Tech/Tools →Engineering Skills →Circuits	ESTT I.B.0	138	36.90%
Academic Advising →Advising	ACAD V.0.0	130	34.76%
Engineering Specific Tech/Tools →Engineering Skills →Sketching	ESTT I.E.2	117	31.28%
Math Skills and Applications →Calculations →Estimation	MATH IX.C.0	115	30.75%
Engineering Profession →Images of Engineering in Today's Society →Roles and Responsibility	ENPR II.A.0	111	29.68%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Communication →Oral and Visual	COMM III.0.0	107	28.61%
Engineering Specific Tech/Tools →Software →Microsoft Office →Excel	ESTT II.D.2	99	26.47%
Engineering Profession →Relevance of the Profession	ENPR I.0.0	96	25.67%
Academic Advising →Advising →Introduction to Departments	ACAD V.E.0	91	24.33%
Communication →Oral and Visual →Presentations	COMM III.A.0	88	23.53%
Engineering Specific Tech/Tools →Software →Programming →Matlab	ESTT II.A.3	85	22.73%
Engineering Specific Tech/Tools →Engineering Skills →3-D Visualization	ESTT I.E.1	84	22.46%
Engineering Specific Tech/Tools →Software →Programming →C++	ESTT II.A.4	74	19.79%
Engineering Specific Tech/Tools →Engineering Skills →Statics	ESTT I.C.0	73	19.52%
Engineering Specific Tech/Tools →Engineering Skills →Material Property and Structure	ESTT I.H.0	71	18.98%
Communication →Written →Reports	COMM II.A.0	63	16.84%
Academic Advising →Advising →Introduction to Campus	ACAD V.D.0	62	16.58%
Design →Criteria and Constraints	DESN IV.0.0	62	16.58%
Academic Advising →Advising →Plan of Study	ACAD V.A.0	61	16.31%
Engineering Profession →Engineering History	ENPR V.0.0	61	16.31%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Manufacturing	ESTT III.A.5	61	16.31%
Math Skills and Applications →Calculations →Graphing	MATH IX.B.0	61	16.31%
Design →Engineering Design Process →Creativity and Curiosity	DESN I.D.0	59	15.78%
Math Skills and Applications →Geometry	MATH X.0.0	59	15.78%
Engineering Specific Tech/Tools →Engineering Skills →Engineering Science	ESTT I.I.0	58	15.51%
Engineering Specific Tech/Tools →Hardware →Shop Experience	ESTT III.A.0	56	14.97%
Latent Curriculum/Professional Skills →Ethics →Codes and Standards	PROF II.A.0	55	14.71%
Academic Advising →Community	ACAD I.0.0	53	14.17%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Basic Surveying	ESTT III.B.3	51	13.64%
Design →Engineering Design Process →Fundamentals of Design	DESN I.A.0	48	12.83%
Design →Problem Solving →Problem Formulation	DESN III.A.0	48	12.83%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Profession →Definition and Vocabulary →Nature of Engineering	ENPR VI.A.0	48	12.83%
Engineering Specific Tech/Tools →Hardware	ESTT III.0.0	48	12.83%
Math Skills and Applications →Other Topics	MATH XI.0.0	45	12.03%
Engineering Specific Tech/Tools →Engineering Skills →Mechanics	ESTT I.D.0	44	11.76%
Design →Engineering Analysis →Data Collection and Statistical Analysis	DESN II.A.0	42	11.23%
Design →Project Management	DESN V.0.0	42	11.23%
Global Interest →Concern for Society →Design Safety	GLIN II.C.0	41	10.96%
Global Interest →Concern for Society	GLIN II.0.0	40	10.70%
Engineering Profession →Professional Societies	ENPR III.0.0	39	10.43%
Academic Advising →Advising →Co-op or Internship	ACAD V.C.0	38	10.16%
Communication →Written →Reports →Documentation (Design →Project Management →Documentation and Management)	COMM II.A.2 (DESN V.A.0)	38	10.16%
Design →Engineering Design Process →Fundamentals of Design →Mathematical Modeling	DESN I.A.1	38	10.16%
Global Interest →Concern for Society →Sustainability	GLIN II.D.0	38	10.16%
Design →Engineering Design Process →Fundamentals of Design →Physical Modeling	DESN I.A.2	36	9.63%
Engineering Specific Tech/Tools →Software →Computer Aided Design →AutoCAD	ESTT II.C.3	36	9.63%
Math Skills and Applications →Calculations →Statistics	MATH IX.A.0	35	9.36%
Design →Engineering Design Process →Research	DESN I.C.0	34	9.09%
Math Skills and Applications →Calculus	MATH II.0.0	34	9.09%
Communication →Visual	COMM IV.0.0	33	8.82%
Latent Curriculum/Professional Skills →Research →Library Resources	PROF IV.A.0	33	8.82%
Math Skills and Applications →Calculations	MATH IX.0.0	32	8.56%
Design →Engineering Design Process →Research →User testing	DESN I.C.1	31	8.29%
Engineering Specific Tech/Tools →Software →Microsoft Office →Word	ESTT II.D.1	31	8.29%
Design →Project Management →Data Management	DESN V.E.0	30	8.02%
Math Skills and Applications →Significant Figures and Measurement	MATH III.0.0	29	7.75%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Communication →Written →Reports →Engineering	COMM II.A.3	28	7.49%
Academic Advising →E-Portfolio Design (Communication →Written →Resume)	ACAD III.0.0 (COMM II.C.0)	27	7.22%
Design →Engineering Design Process →Empirical Design	DESN I.E.0	27	7.22%
Latent Curriculum/Professional Skills →Research	PROF IV.0.0	26	6.95%
Academic Advising →Personal Management →Time Management	ACAD II.A.0	25	6.68%
Math Skills and Applications →Matrices	MATH VII.0.0	24	6.42%
Latent Curriculum/Professional Skills →Critical Thinking	PROF I.0.0	23	6.15%
Design →Engineering Design Process →Fundamentals of Design →Testing Hypothesis	DESN I.A.6	22	5.88%
Design →Engineering Design Process →Fundamentals of Design →Design Review	DESN I.A.7	21	5.61%
Engineering Specific Tech/Tools →Engineering Skills →Material Balance	ESTT I.F.0	21	5.61%
Engineering Specific Tech/Tools →Engineering Skills →Thermodynamics	ESTT I.G.0	21	5.61%
Math Skills and Applications →Units and Dimensions	MATH IV.0.0	21	5.61%
Engineering Profession →Types of Engineering	ENPR IV.0.0	19	5.08%
Engineering Specific Tech/Tools →Software →Programming and Design →Robotics	ESTT II.B.1	19	5.08%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Training	ESTT III.A.1	18	4.81%
Math Skills and Applications →Dimensional Analysis	MATH V.0.0	18	4.81%
Design →Engineering Design Process →Authentic Design	DESN I.F.0	16	4.28%
Engineering Specific Tech/Tools →Software →Programming →Basic Programming	ESTT II.A.1	16	4.28%
Engineering Specific Tech/Tools →Software →Microsoft Office →PowerPoint	ESTT II.D.3	16	4.28%
Engineering Specific Tech/Tools →Software →Microsoft Office →Flowchart	ESTT II.D.4	16	4.28%
Academic Advising →Lifelong Learning	ACAD VI.0.0	15	4.01%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Bread boarding	ESTT III.B.1	15	4.01%
Global Interest →Grand Challenges	GLIN I.0.0	15	4.01%
Academic Advising →Choice of Major	ACAD VII.0.0	14	3.74%
Math Skills and Applications →Abstraction	MATH VIII.0.0	14	3.74%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Latent Curriculum/Professional Skills →Teamwork →Team Management	PROF III.A.0	14	3.74%
Design →Engineering Design Process →Fundamentals of Design →Concept Selection	DESN I.A.5	13	3.48%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Solid Works	ESTT II.C.1	13	3.48%
Engineering Profession →Images of Engineering in Today's Society	ENPR II.0.0	12	3.21%
Design →Project Management →Quality Control	DESN V.D.0	11	2.94%
Engineering Specific Tech/Tools →Engineering Skills →Electromagnetic Systems	ESTT I.A.0	11	2.94%
Engineering Specific Tech/Tools →Software →Microsoft Office	ESTT II.D.0	11	2.94%
Engineering Specific Tech/Tools →Hardware →Shop Experience →CNC	ESTT III.A.4	11	2.94%
Latent Curriculum/Professional Skills →Entrepreneurship	PROF VII.0.0	11	2.94%
Engineering Profession →Professional Societies →Student Organizations	ENPR III.A.0	10	2.67%
Engineering Specific Tech/Tools →Software →Programming →Java	ESTT II.A.2	10	2.67%
Engineering Specific Tech/Tools →Software →Computer Aided Design →MathCAD	ESTT II.C.2	10	2.67%
Design →Engineering Design Process →Reverse Engineering	DESN I.B.0	9	2.41%
Engineering Specific Tech/Tools →Software →Programming →Labview	ESTT II.A.5	9	2.41%
Latent Curriculum/Professional Skills →Patent Search	PROF V.0.0	9	2.41%
Communication →Written →Reports →Lab	COMM II.A.1	8	2.14%
Design →Project Management →Scheduling	DESN V.B.0	8	2.14%
Engineering Profession →Definition and Vocabulary →Nature of Technology	ENPR VI.B.0	8	2.14%
Engineering Profession →Commitment to Discipline	ENPR VIII.0.0	8	2.14%
Engineering Specific Tech/Tools →Hardware →Shop Experience →Lathe, Milling	ESTT III.A.2	8	2.14%
Global Interest →Geotechnical Engineering	GLIN VI.0.0	8	2.14%
Academic Advising →Personal Management	ACAD II.0.0	7	1.87%
Math Skills and Applications →Trig Review	MATH I.0.0	7	1.87%
Latent Curriculum/Professional Skills →Teamwork →Team Dynamics	PROF III.B.0	7	1.87%
Academic Advising →Community →Relationships and Friendships	ACAD I.A.0	6	1.60%
Academic Advising →Advising →Undergraduate Research	ACAD V.F.0	6	1.60%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Design →Engineering Design Process →Authentic Design →Realistic Design	DESN I.F.3	6	1.60%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Arduino Based Project	ESTT III.B.2	6	1.60%
Design →Engineering Design Process →Fundamentals of Design →Refine	DESN I.A.8	5	1.34%
Design →Criteria and Constraints →Design Trade-offs	DESN IV.A.0	5	1.34%
Math Skills and Applications →Linear Regression	MATH VI.0.0	5	1.34%
Communication →Written →Email Writing	COMM II.B.0	4	1.07%
Latent Curriculum/Professional Skills →Leadership	PROF VI.0.0	4	1.07%
Academic Advising →Advising →Study Abroad	ACAD V.B.0	3	0.80%
Global Interest →Concern for Society →Assistive Technologies	GLIN II.A.0	3	0.80%
Global Interest →Biomechanics	GLIN III.0.0	3	0.80%
Global Interest →Bioinformatics	GLIN IV.0.0	3	0.80%
Latent Curriculum/Professional Skills →Research →Quantitative	PROF IV.C.0	3	0.80%
Academic Advising →Personal Management →Stress Management	ACAD II.B.0	2	0.53%
Academic Advising →Academic Integrity	ACAD IV.0.0	2	0.53%
Communication →Visual →Posters	COMM IV.A.0	2	0.53%
Design →Engineering Design Process →Fundamentals of Design →Brainstorming	DESN I.A.4	2	0.53%
Design →Engineering Design Process →Authentic Design →Engineering Feats and Failures	DESN I.F.1	2	0.53%
Global Interest →Concern for Society →Social Entrepreneurship	GLIN II.B.0	2	0.53%
Math Skills and Applications →Calculations →Statistics →Empirical Functions	MATH IX.A.1	2	0.53%
Academic Advising →Advising →Co-op or Internship →Interviews	ACAD V.C.1	1	0.27%
Communication →Professional →Client Interactions	COMM I.A.0	1	0.27%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Arena	ESTT II.C.5	1	0.27%
Latent Curriculum/Professional Skills →Research →Qualitative	PROF IV.B.0	1	0.27%
Communication →Professional	COMM I.0.0	0	0.00%
Design →Project Management →Verification	DESN V.C.0	0	0.00%
Engineering Specific Tech/Tools →Engineering Skills	ESTT I.0.0	0	0.00%

Appendix D continued.

Main Topic →Topic →Sub-Topic →Specific Topic	ID	Frequency	Percentage
Engineering Specific Tech/Tools →Software →Programming and Design	ESTT II.B.0	0	0.00%
Engineering Specific Tech/Tools →Software →Computer Aided Design →Catia	ESTT II.C.4	0	0.00%
Engineering Specific Tech/Tools →Hardware →Shop Experience →3-D Printing	ESTT III.A.3	0	0.00%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools	ESTT III.B.0	0	0.00%
Engineering Specific Tech/Tools →Hardware →Topic Specific Tools →Nanosensors	ESTT III.B.5	0	0.00%
Global Interest →Virtual Reality	GLIN V.0.0	0	0.00%
Latent Curriculum/Professional Skills →Teamwork →Team Management →Work Distribution	PROF III.A.1	0	0.00%
Latent Curriculum/Professional Skills →Teamwork →Team Management →Strength/Weakness ID	PROF III.A.2	0	0.00%

VITA

VITA

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Education
B.S., Mathematics and Applied Mathematics, 2006, Zhejiang University, Hangzhou, China
M.S., Operational Research and Cybernetics, 2008, Zhejiang University, Hangzhou, China
Ph.D., Engineering Education, 2014, Purdue University, West Lafayette, Indiana

Professional Experience
Research Assistant, Engineering Education, Purdue University, West Lafayette, IN (Aug 2010 – Present)
Teaching Assistant, Linear Algebra, Zhejiang University, China (Fall 2006)
Teaching Assistant, Analytic Geometry, Zhejiang University, China (Fall 2004)

Projects

- Engineering Curricula, Matriculation Models, and Institutional Characteristics
  This project aims to describe the composition of the first-year curricula of engineering programs, and determine how curricula, matriculation models, and institutional characteristics may affect engineering student educational outcomes.

- A Comparison Study of Engineering Matriculation Practices
  This project establishes a complete taxonomy to classify U.S. undergraduate engineering programs. The taxonomy considers the matriculation approaches and the term in which the first engineering course is required to take.

- Merit-based Scholarships' Influence on Engineering Student Outcomes
  This project evaluates the effectiveness of merit-based scholarships on promoting engineering student ac-cess and improving student academic performance.

Publications and Presentations

- Xingyu Chen, Catherine Brawner, Marisa K. Orr, and Matthew Ohland. "A Taxonomy of Engineering Matriculation Practices and Introductory Engineering

Courses", poster presented at *the 33rd Annual Conference on The First-Year Experience*, San Diego, CA, 2014

- Matthew Ohland, Marisa K. Orr, Catherine Brawner, and Xingyu Chen. "A Comparative Study of Engineering Matriculation Practices", in *American Society for Engineering Education Annual Conference*, Indianapolis, IN, 2014
- Xingyu Chen, Matthew Ohland, and Russell Long. "The Effects of Merit-based Scholarships on First-year Engineering Student Characteristics and Academic Behaviors", in *American Society for Engineering Education Annual Conference*, Atlanta, GA, 2013
- Xingyu Chen, Catherine Brawner, Matthew Ohland, and Marisa K. Orr. "A Taxonomy of Engineering Matriculation Practices", in *American Society for Engineering Education Annual Conference*, Atlanta, GA, 2013
- Catherine Brawner, Matthew Ohland, Xingyu Chen, and Marisa K. Orr. "Factors Influencing Engineering Student Major Selection", in *Frontiers in Education Annual Conference*, Oklahoma City, OK, 2013
- Xingyu Chen and Matthew Ohland. "The Effect of College Costs and Financial Aid on Access to Engineering", in *American Society for Engineering Education Annual Conference*, San Antonio, TX, 2012
- Qu Jin, P.K. Imbrie, Joe J.J. Lin, and Xingyu Chen. "A Multi-outcome Hybrid Model for Predicting Student Success in Engineering", in *American Society for Engineering Education Annual Conference*, Vancouver, BC, Canada, 2012
- Xingyu Chen, Leah Epstein, and Zhiyi Tan. "Semi-online Machine Covering on Two Uniform Machines", in *Theoretical Computer Science*, 2009, 410, pp. 5047-5062 (5-Year Impact Factor: 0.995