

## **Analyzing and Comparing First-Year Engineering Course Requirements among Institutions**

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Matthew W. Ohland is Professor of Engineering Education at Purdue University. He has degrees from Swarthmore College, Rensselaer Polytechnic Institute, and the University of Florida. His research on the longitudinal study of engineering students, team assignment, peer evaluation, and active and collaborative teaching methods has been supported by the National Science Foundation and the Sloan Foundation and his team received Best Paper awards from the Journal of Engineering Education in 2008 and 2011 and from the IEEE Transactions on Education in 2011 and 2015. Dr. Ohland is an ABET Program Evaluator for ASEE. He was the 2002–2006 President of Tau Beta Pi and is a Fellow of the ASEE, IEEE, and AAAS.

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George D. Ricco is an assistant professor of engineering and first-year engineering coordinator at the University of Indianapolis. He focuses his work between teaching the first two years of introductory engineering and engineering design and research in student progression. Previously, he was a special title series assistant professor in electrical engineering at the University of Kentucky, and the KEEN Program Coordinator at Gonzaga University in the School of Engineering and Applied Science. He completed his doctorate in engineering education from Purdue University's School of Engineering Education. Previously, he received an M.S. in earth and planetary sciences studying geospatial imaging, and an M.S. in physics studying high-pressure, high-temperature FT-IR spectroscopy in heavy water, both from the University of California, Santa Cruz. He holds a B.S.E. in engineering physics with a concentration in electrical engineering from Case Western Reserve University. His academic interests include longitudinal analysis, visualization, semantics, team formation, gender issues, existential phenomenology, and lagomorph physiology.

# Full Paper: Analyzing and Comparing First-Year Engineering Course Requirements among Institutions

**Abstract**— There have been a number of studies investigating First Year Engineering (FYE) curricula pathway, but very few discuss the different curricula pathways among institutions with FYE matriculation.

This study aims to analyze and present the curricular pathways of three institutions. The study also presents the trends and changes in FYE curricula pathways across the past 30 years. This research uses the course catalogs of three large engineering institutions. The courses required for FYE students is categorized into six categories: general engineering, mathematics, science, engineering for a specific major, computer science and general education.

The preliminary result shows the variety of curricular pathway patterns among these three institutions. The results also show the changes across the past 30 years. However, investigating the outcomes of each of the curricula patterns needs further investigation using student data – particularly as more institutions are added to the study.

**Keywords**—*Curricular pathways, Course requirements, Higher education*

## I. INTRODUCTION

First-Year Engineering (FYE) programs are formal programs that teach students introductory courses along with science and mathematics courses such as calculus, physics, and chemistry [1]. The intention of creating FYE programs is to provide students with early engineering experiences, help them make an informed choice about their future engineering discipline and create an environment for engineering faculty to transition students into engineering [2]. Research focusing on FYE programs has addressed curricular design and coursework to promote students' success [3]. Furthermore, Reed et. al. noted that FYE programs improve students' persistence within engineering and is the quickest path to graduation [2].

Orr et al. observed that universities in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) use one of six matriculation models [1]. The first model is the one noted earlier which admits first-time-in-college (FTIC) students into a formal FYE program that focuses on broad engineering coursework, mathematics, physics and chemistry. Students are required to complete this program prior to declaring their engineering major. The second matriculation model enrolls FTIC students directly into an engineering program. This mathematics and science requirements in this model are typically the same as that of FYE programs [1]. The third model enrolls students for a period as undesignated engineering students prior to enrolling them into a specific engineering major. The fourth model require students to complete two years of general education prior to enrolling into a specific engineering major. Students in these two latter models are expected to fulfill the engineering mathematics and science requirements for engineering programs during those two years. The fifth matriculation model enrolls students into a common first year program where students are eligible to declare a major "preference" but cannot enroll in a program without fulfilling the first-year program requirements. In the last matriculation model mentioned by Orr et. al., FTIC

students may matriculate into engineering programs after taking university level general-studies programs [1].

To study engineering programs curriculum researchers have used different categorization models to differentiate engineering coursework. Adelman created an empirical core curriculum that generalized 21 core course categories that accounted for 60% of the credit hours engineering recipients earned [4]. He reviewed the changes in empirical core curriculum between 1972-1984 and 1982-1993 and noted that compared to any other course, calculus took the most time. Adelman highlighted four courses that engineering students frequented outside of the STEM fields which are English composition and technical writing, introduction to economics, general psychology, and introduction to management [4]. To navigate the influence of the changes resulting from the implementation of major changes ABET's Engineering Accreditation Criteria, EC 2000, Lattuca et. al. conducted research based on feedback from 1,400 faculty members and program chairs [5]. The research team concluded that professional skills such as communication, teamwork, and technical writing became more emphasized in the engineering curriculum since the introduction of the new ABET outcomes [5]. In 2009, Sheppard et. al. research team conducted a qualitative study that categorized engineering curricula into four independent blocks: the first block includes general science, fundamental engineering science, and mathematics [6]. The other three blocks are lab, design, and ethics courses. Sheppard et al. indicated how engineering programs introduced theory before practice where open-ended design and lab courses were at a later stage of the curriculum. They noted that engineering ethics, humanities, and social science coursework were not treated as an integral part of the engineering curriculum [8]. Chen conducted a nationwide examination of first year engineering curricula [7]. She categorized the first-year engineering courses into five categories: (1) engineering, (2) mathematics, (3) science, (4) computer science, and (5) general education or free electives. In this paper, we analyze the required courses for FYE students. To be able to compare the requirements among institutions and across multiple years, we categorize the courses using a revised categorization used by Chen [7]. We classify first year engineering courses into six categories: (1) general - engineering, (2) engineering for a specific major, (3) mathematics, (4) science, (5) computer science, and (6) general education. This effort will extend this earlier work in FYE course classification. Although this paper does not aim to evaluate different course patterns, it can lead to future studies to use the classification and student data to compare different course patterns.

## II. METHODS

We collected data from three institutions' publicly available undergraduate catalogs. We looked at the past 30 years of data from 1988-2018. All three institutions have had an FYE matriculation model for the last 30 years time span. The similarity in student progressions allowed for more reliable comparison between required courses for students. Some institutions provided catalogs in two year intervals, these were split into two identical entries across one year intervals in our data to provide entries for each year, given their policies did not change during this time.

### A. Procedure

We looked through undergraduate catalogs for the sections on first year engineering and required courses, then tabulated them by institution and year. Once a course was identified as a first-year engineering course, it was then given further classifications. These classifications include Term

(TRM), Sequence (SEQ), Course Sequence (COR), Tracks (TRK), Offering Department (OFD), Type (TYP), Number of Courses Required (NCR), Mandatory (MND), Category (CAT), Required Discipline (RQD), Credits (CRD), and Average Sequence Credits (ASC).

## B. Variables

Term includes the fall, winter, spring, and summer sessions. Sequence refers to a group of courses that can satisfy a single requirement. For instance, two different calculus classes where either can satisfy the calculus I requirement would be in the same Sequence. The Course Sequence is a list of all the courses that can contribute to a single requirement. The Course Sequence may not always represent symmetrical values, meaning that a student may have the option to take either one or two courses within a Sequence to satisfy a single requirement for first year engineering. These non-symmetrical values represent Tracks, where a Track is a course or multiple courses that satisfy a single requirement. Offering Department is the department that the course is offered through, i.e. Chemistry, Computer Science, and Mathematics. Type is a classification that splits courses into lectures or seminars. Number of Courses Required represents how many courses a student must take from a given Sequence to satisfy a requirement. The Mandatory classification shows if the course is compulsory, selective, or optional by the department of the student's major. A compulsory course is defined as a course where a student must take a single course without the option of an alternative. A selective course is part of multiple courses a student can choose from to satisfy a requirement. An optional course is one that is recommended by the department but not required. Category is a modification of first-year course classification introduced by Chen [7] which lists courses as one of the following: Engineering, Science, Math, Computer Science, or General Education. We divided the engineering courses into two sub categories: engineering general and engineering specific (which is offered by a specific engineering discipline). Required discipline is defined as the majors for which a course is classified as required for rather than optional. Credits shows the credit hours of a given course. The Average Sequence Credits is calculated by the total number of credit hours for all tracks in a given Sequence divided by the number of courses in that Sequence. Table I is a sample of how the classification of courses is conducted.

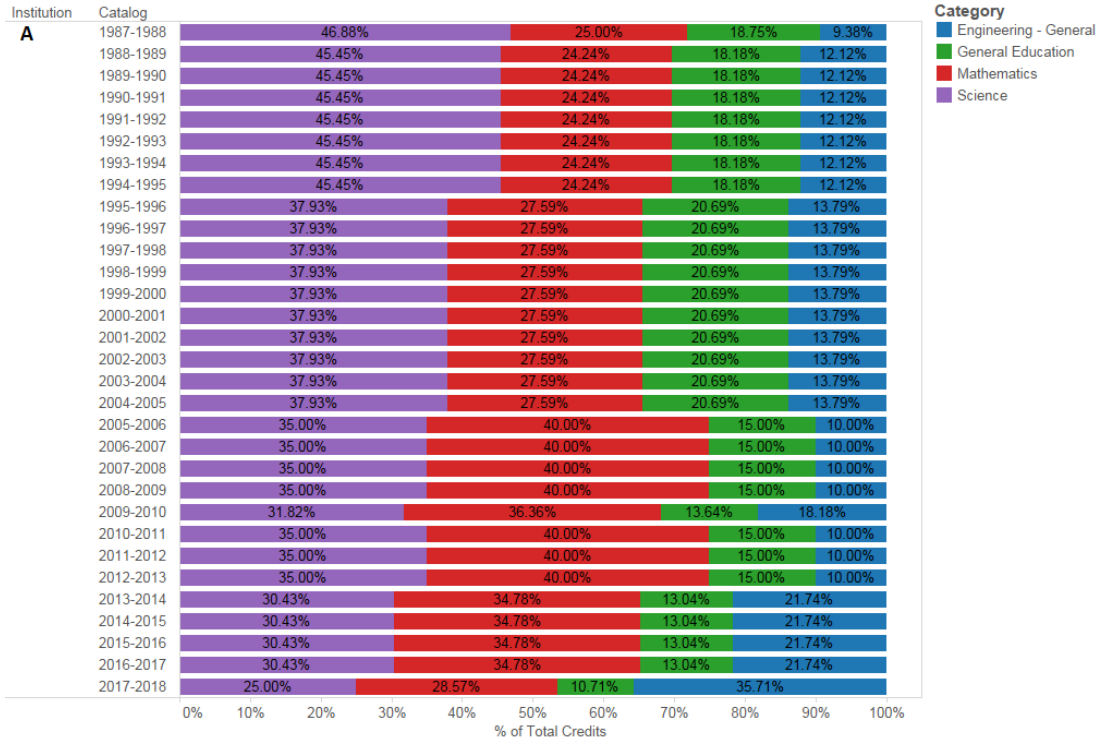
SAMPLE- COURSE CLASSIFICATION VARIABLES

INS	CTG	COR	TRM	SEQ	TRK	OFD	TYP	CRS	NCR	MND	CAT	RQD	CRD	ASC
A	1989-1990	Chemistry I	1	1	1	Chemistry	Lecture	A	2	Mandatory	Science	NA	3	4
A	1989-1990	Chemistry II	3	1	1	Chemistry	Lecture	B	2	Mandatory	Science	NA	3	4
A	1989-1990	Chem for ENGS	1	1	2	Chemistry	Lecture	C	1	Mandatory	Science	NA	5	4

### III. RESULTS

Figures 1-3 illustrate the credit portion of core courses for each of the institutions over the past 30 years. Each institution has changed the portion of required credits for engineering students over this time span.

A. Course requirements across multiple years-Institution A



B. Course requirements across multiple years-Institution B

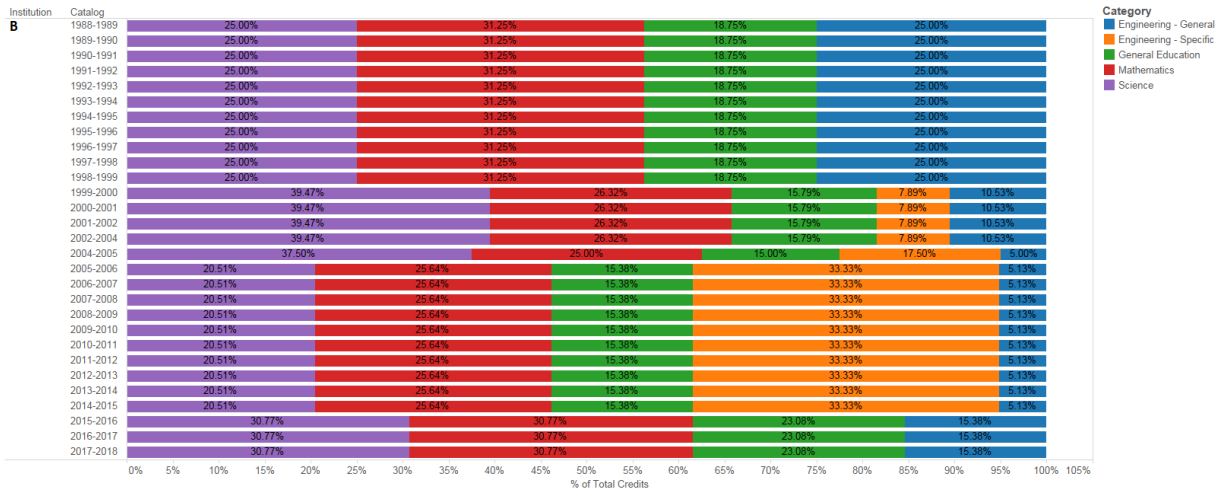
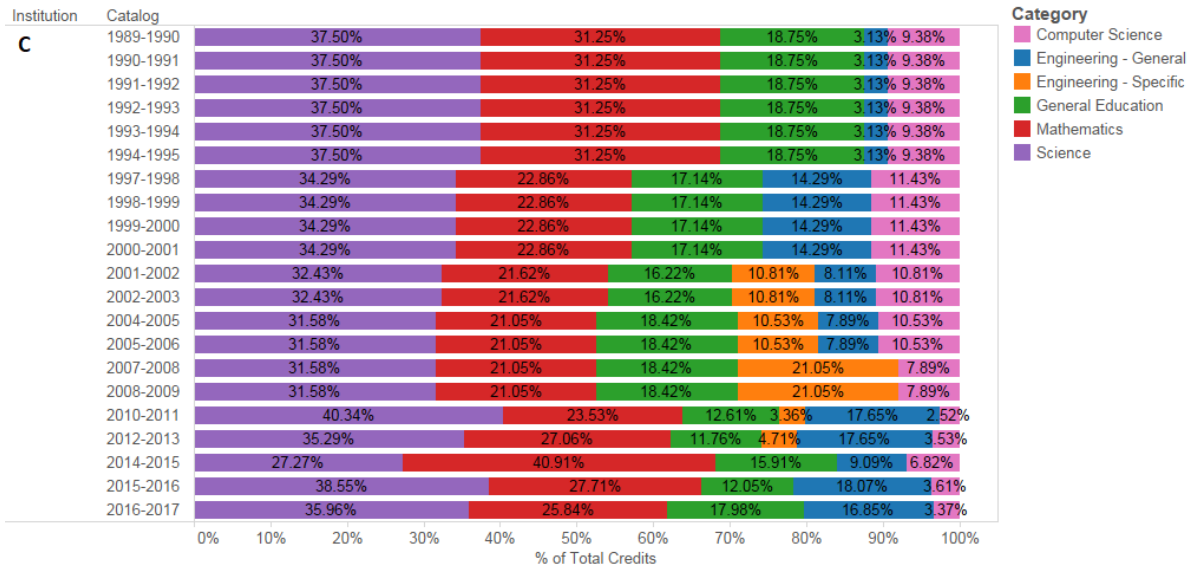


Fig. 3. Course requirements across multiple years-Institution C



As shown, Institution B started with requiring students to take more mathematics credits in comparison to other categories (31%), while Institution A and Institution C were requiring more science credits (47% for Institution A and 37.5% for Institution C) for FYE students in comparison to other course categories. Institutions A and B have been changing the pattern throughout the last 30 years, while Institution C has kept the pattern the same as its early 90s course pattern.

In 1995, Institution A decreased the portion of required science credits 47% to 38%. The required credits dropped two more times for this institution; in 2005, the portion of science credits required for FYE students decreased from 38% to 35% and in 2013 this portion was decreased one more time to 30%. Moreover, in the 2017-2018 academic calendar they had another drop, they reduced this portion to 20%. The reduction of science courses was offset by an increase in the portion of mathematic credits to 28% in 1995 and 40% in 2005. However, in 2017-2018 academic calendar Institution A has reduced the portion of required mathematics credits back to 28%. This decrease was offset by an increase in general engineering credits from 22% in 2016 to 36% in 2017. Other than the jump in the 2017 catalog for general engineering courses, this university has experienced a jump of 11% in the 2013 catalog, where the portion of general engineering credits jumped from 10% in 2012 to 22% in 2013.

Unlike, Institution A which had a clear development of required credits for FYE students, Institution B has tried different changes. Institution B started with an almost evenly distributed portion of required credits in the early 90s (25% science, 31% mathematics, 19% general education, and 25% general engineering). Then in 1999, they increased the portion of science courses required for FYE students by 15%. This jump was offset by a reduction in the portion of engineering general courses by 15%. In this year, they also reduced the portion of mathematics and general education credits and added engineering specific credits to the FYE course pathway. After adding the engineering specific credits to students' pathway, this portion jumped by 10% in 2004, and a year later the portion of engineering-specific credits jumped another 16%, leaving it at 33% of the credits required for FYE students. However, since 2015, this institution no longer has engineering specific credits required for FYE students. These changes in the portion of engineering specific credits were in the cost of reducing other course categories, especially general engineering courses.

Unlike Institutions A and B, which have tried different patterns of required credits for FYE, Institution C has kept largely the same portion of course credits for the last 30 years. This institution is the only institution among these three which has computer science courses embedded into the FYE pathway. The portion of computer science courses has taken almost 10 percent of the required credits. This portion has been decreased to less than 5 percent from 2010 (with an exception of 7% in 2014). Excluding the 2014 course catalog, science credits required for FYE students takes the most required credits in comparison to the other categories. In 2014, this institution increased the portion of mathematic credits from 27% to 41% and reduced the required science courses from 35% to 27%. A year later, the institution resumed the previous pattern.

Like Institution B, Institution C tried to add engineering specific credits to students' pathway. Three years after Institution B added this category to students pathway, Institution C added engineering specific credits to the pathway which took 8% of the total required credits. Adding this new category influenced the portion of required general engineering and general education credits. For two academic calendar years (2007-2009), this institution did not require any general engineering credits for FYE students. Instead, they increased the number of required engineering specific credits from 10% to 21%. Right after 2009, the required general engineering courses were re-added to the requirements and the portion of required engineering specific credits was dropped to 4%. The required engineering specific credits has been removed from the FYE pathway since 2014.

#### IV. DISCUSSION AND FUTURE DIRECTIONS

This paper aimed to investigate the distribution of required courses for FYE students among institutions with an FYE matriculation model. The courses were categorized using a common classification. As a result, the distribution of credits required not only varied among institutions. It also varied with time within institutions.

This research can only show the required course pathway variations among institutions with FYE matriculation models. To investigate the advantages and disadvantages of each of the course pathways, further investigations can be conducted using student data. Reid, et al. [8] introduces a taxonomy which classifies *introductory to engineering* courses (classified as general engineering in this paper). Moreover, future studies can use taxonomies like this to investigate FYE pathways based on their course content and not only the course titles.

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