2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
ASEE
Paper ID #38507

Work in Progress: Knowing Our First-year Students, Meeting Them Where They Are, and Supporting Them for Success

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WIP: Learning About First-Year Students on Their First Day

Introduction

This work-in-progress paper describes an effort to enhance a first-year engineering course by gathering information about students' pre-existing knowledge of engineering. The first-year engineering experience at Case Western Reserve University (CWRU) is in the process of expanding from an optional pilot program to a one-semester required course for all engineering majors. As such, the faculty leading the program are still learning about the range of backgrounds, skills, and attitudes typical of their institution's first-year students. The activity described here serves two sets of intentions:

1) to collect baseline information for introducing students to engineering and building their confidence

2) to help instructors learn about their students' backgrounds and attitudes to tailor that introduction from cohort to cohort.

Speaking to the first motivation, new engineering students can be unsure about what an engineering career entails and are usually unaware of the breadth of available engineering opportunities. Additionally, some first-year students have a narrow view of the skills that contribute to becoming a successful engineer. The course instructors hoped that collecting and discussing these initial thoughts would lay a foundation to develop curiosity, confidence, and a sense of belonging in all students, regardless of their backgrounds.

Regarding the second motivation, it is possible that the students who elected to take the pilot course were not representative of the institution's first-year engineering population. If this is the case, adjustments might be indicated for the full-scale program. Another potential source of student variation could come from whether the course was taken in the fall or spring term; these differences would likely persist into the future. Collecting some information about differences in student background would help determine whether elements of the course should be adjusted to achieve a suitable balance of challenge and support for the students.

This paper shares some of the motivation in developing the course structure, outlines the exercise developed to gather information from the students, details an initial analysis of the data that resulted, and describes next steps.

Context: History and Structure of the Program

Course History and Student Population

The first-year engineering experience at CWRU began as a pilot course in 2019. The motivation behind developing the program was to improve student satisfaction and retention, as has been experienced at other universities implementing similar programs [1, 2]. There were initially 24 students per semester in a single section, expanding to multiple sections in 2021 (Table 1). Starting in Fall 2022, the single, three-credit, first-year engineering course, ENGR 130, became a requirement for engineering students. Students may take the course in either the fall or spring semester.

In Fall 2022, the university had 6,081 undergraduate students, of which 18% were international. There were 1061 engineering students, of which 26% were female.
The course enrollment for academic year 2022-23 was 205 students in the fall semester and 155 students in the spring, with a maximum enrollment per section of 44 students. More than 95% of students taking ENGR 130 are first-year students who have not yet declared an official major.

Table 1. Course enrollment

Year	Semester	Enrollment	Sections
2019	Spring	17	1
2019	Fall	21	1
2020	Spring	15	1
2020	Fall	8	1
2021	Spring	36	2
2021	Fall	118	4
2022	Spring	112	3
2022	Fall	211	5
2023	Spring	156	5

Course Goals and Structure

The course goals are for students to learn: (1) to analyze data in the context of engineering problems, (2) programming using MATLAB, (3) to work effectively in teams, (4) to prototype using hand tools, basic CAD, and 3D printing, and (5) to articulate differences and overlaps between engineering disciplines and practices. These course goals are stated on the syllabus. Students in ENGR 130 meet in two 75-minute laboratory sessions and a single, combined 75-minute lecture per week. In the lab, students complete two-week modules that combine MATLAB programming and hands-on design projects, working in teams of three or four.
In lecture, students learn computer programming skills using MATLAB. There are also guest lecturers every week to teach students about different engineering disciplines and career paths.

The First Day Survey Activity

In academic years 2021-22 and 2022-23, a three-question anonymous survey was administered to students on the first day of class. With just a small amount of variation by semester and instructor, this was essentially the first activity of the semester, before any details of the course were discussed. This activity is inspired by the work of Walvoord and Anderson [3], who suggest several types of questions to ask students on the first day of a course to help frame discussions about learning goals. Responses to these questions provide a dual benefit: they give the instructor a picture of the students' motivations and backgrounds, and they also prime the students to understand the instructor's goals for them. The questions are:

1) What are your <u>learning goals</u> for this course?
2) What questions do you have about engineering?

3) What skills are you bringing with you that you think will help you be successful in this course?

Question 1 comes directly from Walvoord and Anderson, who note that it is important to clarify to students that getting a good grade or satisfying a requirement is not a learning goal [3]. Question 2 provides students with the opportunity to ask any questions they might have about engineering. While some students come from families of engineers or high schools that offer engineering courses, others are in the course simply because someone they knew suggested they might like engineering, even if that person could not tell them what engineers do. Previous work shows that this range of backgrounds exists and that it influences major selection [4]. Question 3's initial motivation was to prompt every student, but particularly those who might be feeling uncertain about whether they could be successful as engineers, to identify strengths that they could draw on in the course. The instructors hoped it would also help students recognize the array of skills necessary for success in engineering and set the stage for a discussion of how the course is intentionally designed to help them grow and learn in multiple dimensions.

A summary of the responses is shared with the students as soon as practical after the survey is taken. There are always more themes than any one student expresses. Students' attention is called to the breadth of responses to help them appreciate the diversity of motivations, goals, and backgrounds in the class. Those who are experiencing uncertainty about what engineering is and whether they would like to major in it realize that other students have similar questions. Those who view engineering as relying solely on technical knowledge may have their eyes opened by the responses of their classmates. The goal is that each student sees themselves in some of the responses and also realizes the vast opportunity they have to learn from those around them. Sharing the summary also naturally leads to a discussion about habits for student success and gives the instructors an opportunity to clarify course goals.

For the instructors, the responses serve as a way to "take the pulse" of the class overall, as well as their particular section of the course. For example, if there were many students in one section reporting experience in coding, the instructor may adapt the teaching approach so that those experienced students are given opportunities during the lab to expand their coding skills. In contrast, an instructor leading a section where the students are expressing concerns about being left behind due to no previous coding experience may need to provide extra reassurances and provide the students more opportunities in class to practice the fundamentals. Throughout the term, instructors can weave in contexts and examples to address some of the students' questions. Note that these are small-scale adjustments, not major changes to course content or goals.

Additionally, instructors use the resulting data to inform multiple aspects of the course. For instance, in fall 2021, a new student resource was developed with answers to the most common questions asked about engineering. This resource continues to be enhanced each semester as more students contribute questions and the instructors add answers from relevant experts. The responses not only help students adjust to the course, but point them to additional activities and services to help them transition to the university and the college of engineering.

As the program has grown from pilot to requirement, a wide range of conjectures have been shared by administrators, faculty, and students about how the student population served by the course might change. These conjectures have been concerned with the potential impact of such differences as student motivation, awareness, academic preparation, engineering background, or career goals on student engagement with and success in the course. By continuing to implement the survey each semester, at least through the first year of full-scale implementation, the instructional team can determine if there are indeed measurable differences between the general first-year engineering student population and the "volunteers" who participated in the early versions of the course. If differences are found, they can be used to anticipate potential differences in student comfort with particular aspects of the course and to make modifications to meet the students where they are. These data will also be combined with other information gathered throughout the semester to assess the program's impact, but that is beyond the scope of this paper. Here we focus on two broad questions:

1) Are there any differences in the response patterns on the survey according to whether the students were taking the course in the fall or in the spring semester?
2) Are there any differences in the response patterns on the survey according to whether the students were taking the course before or after it became required?

Methodology

Responses for the four semesters during the '21-'22 and '22-'23 academic years were collected and separated by section. A phenomenological interpretivist perspective was used, since the data and conclusions drawn from them are the products of the environment in which the students and instructors were working [5, 6]. Two researchers each took two sections' worth of responses at random to initially code, without knowing which semester or section they represented. They then discussed the trends each saw in the data, reduced and refined the codes, and applied the modified coding scheme independently to two new sets of responses to check for inter-rater reliability. The reliability was greater than 90%; further discussion improved the reliability and led to the definitions of the codes shown below. The researchers then applied the revised coding scheme individually to responses from additional course sections. Throughout, the sections were chosen at random. They also re-coded the responses from the initial rounds of coding. After eight sections had been coded, one researcher checked to see how many sections had been selected from each semester, and then purposefully selected two more to code, ensuring a representative sample. The qualitative coding was combined with a semi-quantitative analysis to describe trends in the content of the student submissions. Note that a single student's response could generate multiple codes, depending on how many items the student listed.

A total of 363 student responses were included in the data set, distributed as shown in Table 2

Table 2. Distribution of coded samples by semester and academic year

	'21-'22	**'22-'23**	**Total**
Fall	84	112	196
Spring	44	123	167
Total	128	235	363

To compare the response patterns between fall and spring, and also between academic years, chi-squared goodness-of-fit tests were run for each survey question, using any categories that accounted for 5% or more of the total codes for that question.

Results and Discussion

The code categories accounted for 93%, 96%, and 93% of the learning goals, engineering questions, and success skills, respectively, in the student responses. The codes for each set of question responses are summarized in Tables 3 through 5. Brief descriptions are given for the categories that accounted for 5% or more of the responses to that question. Additional codes are listed below the tables from high to low frequency.

Student Learning Goals

The most common reported learning goal (31% of responses) was to learn about computer programming and/or MATLAB (Table 3). The next most common goals were learning about the engineering field (10%), skills (10%), and disciplines (9%), followed by hands-on projects (7%), real world practices (6%), is engineering for me (5%), and problem solving (5%).

Table 3. Summary of student learning goals

Code	%	Student Wants to Learn
Coding	31	computer programming or MATLAB specifically
Engineering Field	10	more about the field of engineering, what engineering is and/or what engineers do
Engineering Skills	10	general or specific engineering skills that can be applied to courses and/or engineering jobs in the future
Disciplines	9	about the variety of engineering disciplines, the differences between them, and/or the overlaps among them
Hands-on Projects	7	how engineers work with tools to physically create products or devices; s tudents who want to learn about non-specific engineering projects are also included
Real World	6	how engineering practices are applied outside of the usual classroom setting
Is Engineering for Me	5	if they have the interest and/or abilities for an engineering career
Problem Solving	5	different or more effective methods for solving problems

Other codes: Career, Design, Teamwork

Questions about Engineering

Table 4 shows the most common questions were about what engineers do on a day-to-day basis (17% of responses), followed by coding (12%), disciplines, (11%), and the definition of engineering (9%). Rounding out the topics that contributed at least 5% to the questions were education (7%), career (6%), and design (5%).

Table 4. Summary of questions about engineering

Code	%	Student Asked About
Real World	17	what engineers do on a day-to-day basis
Coding	12	why engineers need to learn how to code or how coding is incorporated into engineering
Disciplines	11	differences or overlaps between engineering subfields; s ome questions about choosing a major also fit in this category
What is Engineering	9	how to define engineering, or how it differs from other fields; this question also appeared verbatim many times
Education	7	the preparation to become a practicing engineer, not questions specific to the programs at CWRU
Career	6	the future job market and/or income potential in engineering
Design	5	design processes or how engineers go about creating things

Other codes: Course Specific, Major Specific, Is Engineering for Me, Institution Specific, Skill Specific, Types of Engineers, Teamwork, Daily Life

Success Skills

Students listed a wide array of skills that would help them in the course, as shown in Table 5. The most common skill was computer programming (12% of responses). The next most cited skills were problem solving (10%), teamwork (9%), math (7%), hands-on activities (7%), learning (6%), and hard work (5%).

Table 5. Summary of success skills

Code	%	Student Described Experiences or Abilities in
Coding	12	computer programming
Problem Solving	10	problem solving; responses that mentioned analytical thinking, critical thinking, or logic were also included in this category
Teamwork	9	teamwork or collaboration
Math	7	math
Hands-on	7	hands-on fabrication, electronics, or prototyping experience, such as 3D printing, woodworking, or breadboarding; s ome students also described tinkering or repairing things around the house
Learning	6	learning new things, learning quickly, or enjoyment of learning
Hard Work	5	working hard or being dedicated

Other codes: Science, Creativity, Engineering, Communication, CAD, Resilience, Robotics, Organization, Design, Positive Attitude, Detail Oriented

Table 6 shows the code distribution by percentage for each question for each sub-group. These are the data for the chi-squared tests.

Table 6. Summary of codes by subgroup and question

Code	Fall	Spring	21-22	22-23
Learning Goals				
Coding	23	44	24	36
Engineering Field	12	8	12	9
Engineering Skills	9	11	9	10
Disciplines	11	6	11	8
Hands-on Projects	9	4	10	5
Real World	9	3	7	6
Is Engineering for Me	6	4	9	3
Problem Solving	4	6	4	5
Questions				
Real World	21	16	24	16
Coding	8	20	11	14
Disciplines	13	11	14	11
No Questions	9	14	12	11
What is Engineering	10	10	9	11
Education	8	6	7	7
Career	6	8	5	8
Design	7	3	5	5
Skills				
Coding	11	15	10	14
Problem Solving	10	10	11	9
Teamwork	10	9	10	10
Math	8	6	8	7
Hands-on	8	6	8	7
Learning	6	6	8	4
Hard Working	4	6	5	4

The chi-squared tests yielded three statistically significant results. In the fall-spring comparison, the distribution differences were significant for the learning goals ($P < .0001$) and the questions asked ($P < .001$). The academic year comparison also showed a difference in the distribution of learning goals ($P < .001$).

Discussion

With the caveat that the current analysis is broad, there are plausible possible explanations for the differences that emerged. The majority of students who take the course in the spring have already had at least one term on campus, and in that time, regardless of whether they have engaged in any engineering coursework, they have interacted with other engineering students, including upper-classmen, and participated in events to help them choose a major. This might account for more fall students wanting to learn about the engineering field in general, engineering disciplines, and what engineers do in real life. It could also contribute to the spring population asking less questions than their counterparts in the fall. Many of the spring semester students also have doubtlessly heard about the course from students with previous experience, and likely heard the course described (whether the instructors agree with this portrayal or not) as "the MATLAB class." This could account for the increased awareness of coding in the spring.

The comparison of learning goals between the '21-'22 and '22-'23 academic years bears a similarity to that between the fall and spring semesters. This may indicate that the students who elected to take the course in the first year of the study were those less familiar with engineering than the average first-year student at the institution, but additional data are required to determine if this is actually the case.

Finally, it should be noted that no significant differences were seen in the success skills reported by students. Due to the open-ended nature of the question, this does not necessarily mean that there are no differences in background experiences. All that is known at this point is that the skills that came to mind when students were answering the question were similar from cohort to cohort. Some aspects of student background can be probed in more detail with other data sources, should that be an avenue that the researchers desire to investigate.

Future Work

The current results suggest several different directions of work. First, the current analysis will be expanded to include all sections. However, while the current methods capture broad content areas, they do not describe the nuances of students' learning goals or the information they are seeking via their questions. Therefore, a second coding scheme will be developed to analyze the depth of the learning goals and engineering questions. It is anticipated that this additional coding will be based on Bloom's taxonomy, similar to that described in Harper et al [7].

Additionally, while initially it appears there are no significant differences between sections within the same semester, this should be probed more rigorously. In particular, due to scheduling, one section in Fall '22 answered the questions after they had been to one lecture for the course. If it is found that these students responded differently, they will be kept separate in the final analysis; regardless of the outcome, the results will yield interesting information regarding that first lecture's impact, or lack thereof, on student expectations and mindset.

Finally, the research team will explore the correlations between responses at the student level, to determine if there are patterns. If patterns are found, the team will develop "personas" of students to describe the types of students enrolling in engineering at the university, as well as the distribution of these personas. Such work would not only inform the structuring of the first-year engineering experience but would also be of interest to the wider college of engineering.

These results will be combined with other data to assess the initial impact of this program, informing future refinements. Regardless, the instructors will continue this activity both to get a glimpse into their students' backgrounds and motivations, and also to communicate their expectations, goals, and commitment to the success of every student.

References

[1] G.W. Bucks, K.A. Ossman, J. Kastner, and F.J. Boerio, "First-year engineering courses effect on retention and workplace performance," ASEE Annual Conference and Exposition Conference Proceedings, 2015.

[2] D. Knight, J. Sullivan, and L. Carlson, "Staying in engineering: effects of a hands-on, team-based, first-year projects course on student retention," ASEE Annual Conference and Exposition Conference Proceedings, 2003.

[3] B. E. Walvoord and V. J. Anderson, Effective Grading. Jossey-Bass, 2011.

[4] J. Main, A. Griffin, X. Xu, and A. Dukes, "Choosing an engineering major: a conceptual model of student pathways into engineering," J. Eng. Ed. 111(1) 40-64, 2022.

[5] N. Denzin and Y.S. Lincoln, eds., The Landscape of Qualitative Research. Sage Publications Ltd., 2013.

[6] M. Koro-Ljungberg and E. P. Douglas, "State of qualitative research in engineering education: metaanalysis of JEE articles 2005-2006," J. Eng. Ed. 97(2) 163-176, 2008.

[7] K. A. Harper, E. Etkina, and Y. Lin, "Encouraging and analyzing student questions in a large physics course: meaningful patterns for instructors," J. Res. Sci. Teach. 40, 776–791, 2003.