Evaluating the Perceived Value of a First-Year Engineering Experience

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Full Paper: Evaluating the Perceived Value of a First-Year Engineering Experience

Purpose

The national effort to remain a leader in scientific exploration and technological development has redoubled educational efforts to not only introduce students to the field of engineering at younger and younger grade levels, but also to place more effort on retaining the students who ultimately choose engineering as a career path. As a result, more institutions are placing a higher value on first-year engineering introductory courses, a key component of retention at the undergraduate level [1].

However, with engineering being an incredibly broad field, there is relatively little agreement from institution to institution, and often from department to department within the same college, on the content and skills to address in a first-year course [2, 3]. Furthermore, previous studies have shown that students more often leave their engineering degree programs due to a lack of interest and/or a poor classroom environment than for reasons related to challenging technical content [4, 5]. To address these issues, researchers have investigated best practices for retaining students and have identified positive correlations between classroom practices and student confidence and commitment. Yet holes still exist in our understanding of the value students place on their first-year coursework, particularly as they relate to their later experiences in engineering classes and professional work.

At Ohio Northern University, the first-year engineer course sequence is expected to provide a common foundation upon which all students are able to build their knowledge bases and skillsets. Yet additional analysis is necessary to evaluate students' true perceptions of their first-year experiences. To address this knowledge gap, focus group interviews and surveys were conducted to gather reflections and input from upper-level students. Outcomes from the subsequent analysis are intended to provide deeper insight into the value that students place on their initial experiences with engineering at the college level, allowing educators to better involve first-year students in class while at the same time prepare them for their chosen professional pathways. The following research questions drive this study:

After experiencing higher-level engineering coursework . . .

1) What value do students place on their first-year engineering experiences?
2) What connections do students make between their first-year engineering experiences and subsequent engineering courses and professional experiences?
3) What technical content and skills do students suggest for a first-year engineering experience?

Course Background

The first-year engineering experience at Ohio Northern University is comprised of two sequential 3-credit hour courses. During the time at which the study participants took the course, the fall semester was comprised of several multi-week projects and contained various topics such as visual modeling, technical writing, basic circuits, Excel, units of measurement, ethics,

engineering design fundamentals, and carrying out calculations with proper significant figures, among other items. The second semester was devoted to an open-ended hypothetical design project aimed at alleviating poverty in a developing country; topics in this course included the engineering design process, project management, social entrepreneurship, product life cycles, and the Engineering Grand Challenges. Learning objectives across both semesters also included effective communication and teamwork. Classroom activities were largely team-based, with students commonly working in groups of four. Course sections were mixed disciplines.

Literature Review

As noted in works by Reid et al. [2, 3], there is little consistency nationwide among courses designed for first-year engineering students. Instructors place widely varying degrees of emphasis upon technical skills (such as design, critical thinking, algebra, fabrication, and robotics) and professional skills (including teamwork, communication, and time management); courses may also serve as an orientation to the college and/or the engineering profession. With so many available topics, courses are often offered as a medley of disconnected units. This approach can unfortunately demotivate students from continuing in the discipline [2, 6].

Others have noted that courses focused strictly on technical skills do not fully prepare students for the professional expectations of engineering [7]. Likewise, an emphasis on design, whereby analysis is largely ignored, may distort students' views of the profession [8]. A balance between technical and professional skills is therefore recommended. For example, such an approach taken by Chapman et al. [9], which strongly connected engineering and society, included active learning, and tied learning outcomes to ABET criteria, resulted in improved student retention and attitudes.

Yet by covering a plethora of knowledge and skills, it is difficult to include any degree of content depth in each area. This is particularly challenging for educators implementing a project-based classroom, an approach that has a wide body of support for fostering student engagement and critical thinking [10, 11, 12]. Since students spend more time investigating, creating, and discovering in a project-based environment, however, content coverage is reduced relative to a traditional lecture-based class setting where knowledge-transfer is more streamlined [13, 14].

Moreover, wide content coverage can be particularly challenging for colleges offering common introductory courses for all engineering majors, since technical knowledge may not be directly related to all disciplines represented in a single classroom. A somewhat siloed approach may consist of discrete short-term projects, each focused on a different discipline [15]. Yet common courses have been shown to benefit students both in terms of retention and in helping them select fitting degree programs [16].

Research Methodology

This investigation was situated as exploratory, whereby participants were posed with open-ended questions in an effort to compel them to reflect back upon their own experiences and identify worthwhile (and lacking) course activities. Four focus group interviews were conducted with a total of twelve juniors and seniors in the college. These interviews centered on six broad,

eliciting questions related to students' general impressions of their first-year engineering courses, the knowledge attained and skills developed in these courses, how their experiences related to other engineering coursework and professional work (e.g., internships), and how they would design a first-year experience themselves. Interviews lasted 55 minutes on average and were audio recorded and transcribed. To further supplement the data, sixteen juniors and seniors completed anonymous online surveys populated with the same questions (there was potential overlap among these two data sets, but it can be assumed that these participant pools largely represent different students).

Gathered data, purely qualitative in nature, was first analyzed by lumping discrete statements into categorized themes (themes were emergent rather than pre-determined in an effort to mitigate researcher bias). Once a collection of common themes were identified, data was re-examined and quantified both by the number of individuals who addressed a specific area (to account for breadth among participants) as well as the number of isolated instances in which a topic was raised (to account for significance). Direct quotes which raised salient points and/or were representative of the most common themes were also identified.

Participants' genders, GPAs, majors, and grade levels were collected in an effort to differentiate among various factors. However, with few exceptions, no discernable correlations were noted among the students' input and their collective groups. This lack of correlation points somewhat to the study's limitations – a limited data set, and wildly different experiences based on an individual's instructor, selected project topic, and perhaps most importantly, teammates. Thus, future investigations will need to include a means for accounting for the effect of these influences on students' valued perceptions. Participant information is provided in Table 1 (ME: mechanical engineering; CEE: civil & environmental engineering; EE/CpE: electrical & computer engineering, EEd: engineering education; PNS: prefer not to say).

Table 1: Participant information

Instrument	*Grade* *Jr, Sr*	*GPA* *<2.5, 2.5-3, 3-3.5, 3.5+*	*Major* *CEE, ME, EE/CpE, EEd*	*Gender* *M, F, PNS*
Focus Groups	6, 6	1, 3, 3, 5	5, 5, 1, 1	10, 2, 0
Surveys	4, 12	2, 4, 6, 4	2, 10, 3, 1	8, 7, 1

Perceived Value

With such a wide variety of topics covered over the first-year course sequence, it is not surprising that the number of valued content items was likewise far reaching, yet spread thin. Figure 1 shows the most common topics addressed during the focus groups and surveys.

The most often discussed topic, in fact the only topic broached in all four focus groups, was the value students placed on their experiences working in teams (identified as worthwhile by 9 of the 12 focus group participants and 9 of the 16 survey takers). One student's take on this topic was as follows: "From the get go, getting [students] to work as a team is super beneficial. Especially in engineering because we're all really awkward and weird and don't know how to talk to people."

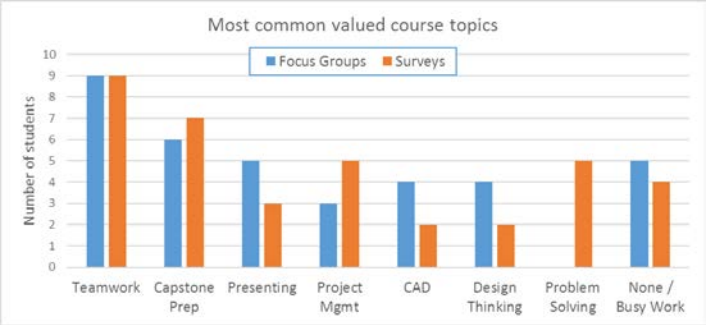

Figure 1: Most common course topics discussed

Second to teamwork, students viewed their experiences, particularly their second-semester poverty alleviation project, as quality preparation for their senior capstone projects. Notably, students largely did not identify any other courses as being directly connected to their first-year coursework. This was unexpected since, to an extent, several of the first-year course activities were developed to familiarize students with subsequent courses (e.g., circuits and statics calculations). However, these activities were relegated to a somewhat cursory overview, and as noted by two students, there was not enough "technical content" in the first-year courses to provide benefit, particularly since this content was reviewed at the beginning of future courses.

Moreover, while three total participants later recommended that introductory lessons to second-year engineering courses should be presented during the first year, an equal number stated the opposite. One student summed up his feelings about this type of content as follows: "For me the lecture days, when they were trying to teach you … they went about it like we all had background in it and a lot of us don't. Like one day they tried to teach us about moments and I had no idea. I think it was the next year in statics we learned about moments and I was like, 'Oh, that all makes sense.'" Another noted about AutoCAD in particular, "It was definitely nice to touch on and do. But it wasn't very in-depth, so it didn't seem like it really helped a whole lot. It was more of making you aware of it being there."

In significantly fewer quantities, students discussed the importance of presenting to an audience, learning basic CAD skills (the only technical skill reported by more than two students in either set of data), as well as improvements to their design thinking and problem solving capabilities. Some students felt there was no value to the experience, or viewed it as busy work, most often because they felt the content was too general to be of any real use specific to their own majors, and because it was viewed as disjointed, "jumping from one topic to the next," as one student explained.

Recommendations

Given an open slate to design their own first-year engineering experience, the students were not shy about offering suggestions. Yet other than a few key commonalities, the students' responses were so varied that any attempt to meet all of their individual requests would be wholly impractical. Ranging from MATLAB lessons to utilizing upperclassmen as mentors to spending significant time covering time management techniques, the twelve focus group participants suggested 28 disparate topics that should be covered during the first year (the survey participants, less apt to elaborate or build off one another's ideas, identified 14 topics).

The most common topic discussed was technical skill-set development in areas such as specific CAD and other software programs and fabrication tools (focus group participants identified a dozen different areas), again pointing to the issue of breadth versus depth of coverage. These suggestions included 3D printing, drafting by hand, SolidWorks, Microsoft Project, and Engineering Equation Solver (EES), among others. In general, students acknowledged without prodding that teaching such a variety of tools would limit their exposure to the project component of the coursework, and understood the difficulties in meeting all majors' needs.

Notably, while students were well aware as freshmen that they were likely touching on content areas that they would not see again in their own disciplines, only two survey participants and no focus group interviewees recommended splitting the first-year experience into sections by major. On the contrary, many students appreciated gathering a better understanding of majors outside their own. One student pointed out, "It was nice though, to be able to see what other engineers are doing and how they work and how I need to work and being able to work with them on a project that might not be my discipline per se." Several others noted that although they had selected their majors before arriving to campus, they were unsure about their selection and the engagement with discipline-specific projects helped solidify their decisions.

This was indeed the most emergent point (although it only appeared in 2 survey responses, it was recommended by 9 in the focus groups) – students suggested that the first semester should consist largely of discipline-specific, short-term projects to provide insight to the different offerings in the college (an admittedly impractical approach for large institutions). As one student noted: "I do like having them do the entire design process from start to finish on a big project, although I think it should really be encouraged in the small ones, the small projects too that are disciplinary related."

Other discrete topics that were addressed by at least 3 individuals in each data set included providing more hands-on activities (5 focus group, 3 survey), offering more guidance in the open-ended design project (4, 3), and providing more directed technical writing instructions (4, 4). Expressing an interest in learning more about basic wood/machine shop tools was also discussed by several focus group participants (7), though was only noted by 1 survey participant.

Key Takeaways

Lessons learned from the study point to the following:

- Course activities should continue to emphasize teamwork
- The first semester should include short-term, discipline-specific projects with skill-building activities interwoven; deeper content will help students select their majors
- The second semester should remain a long-term, open-ended project to allow students to pursue their own interests and tap into their creativity, yet contain well-defined boundaries and supportive instructor guidance
- Connecting technical skills with course activities and engineering content will provide a more meaningful experience; coursework should not be made up of isolated units

A lasting common thread present throughout much of the data was students' insistence for improved connections among the topics covered during their first-year experience and their later coursework. These connections would help students answer the question "Why are we doing this?" and would help tie some of the professional skills, design thinking, and interdisciplinary appreciation throughout a more cohesive four-year experience. The two-year gap that exists between the first-year course and senior capstone provides opportunity for engaging students in more design during their college tenures and providing motivation to persist. Unfortunately, only one student in the study explicitly noted that the first-year sequence offered a motivating experience, demonstrating a missed opportunity for improving retention. One student captured this sentiment with the following statement: "You could be like we're doing a project that was going through the entire engineering design process. You don't get that until capstone again. It's kind of like a confidence booster for freshman to be like, 'Yes I can do this.'"

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