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A reimagined first-year engineering experience implementation: Structure, collaboration, and lessons learned.

Dr. Devlin Montfort, University of Portland

Dr. Montfort is an Assistant Professor in the School of Chemical, Biological and Environmental Engineering at Oregon State University

Jason H. Ideker
Dr. Jennifer Parham-Mocello, University of Portland

I am interested in computer science education research related to K-12 curriculum, diversity in computer science, undergraduate computer science learning, and adult and teacher training.

Rowan Ezra Skilowitz
Dr. Natasha Mallette P.E., Oregon State University

Dr. Natasha Mallette is a licensed professional engineer with expertise in engineering education focusing on effective curricular design, inclusive teamwork, and social justice. She has over 6 years of work experience as a design, process and research engineer in nuclear energy, renewable technologies, and various manufacturing facilities. In 2020, she received the OSU Breaking Barriers in Education Award, which recognizes high impact in teaching, mentoring, and advancing gender equity in higher education. She is fluent in the fields of energy, chemical processes, and engineering design and is currently the Director of Engineering+, the College of Engineering's first year experience program.

A reimagined first-year engineering experience implementation: Structure, collaboration, and lessons learned.

Abstract

The reimagined first-year experience at Oregon State University for engineering and computer science students was first implemented during the 2021-2022 academic year. The new Engineering+ Program is innovative because it was designed to holistically support students as engineers (through redesigned curricula and through co-curricular events), students (through engineering relevant social justice content), and community members (through team-based design projects matching student interests to interdisciplinary technical themes).

The curricula developed by the 40 participating faculty were guided by specific pedagogical principles: small-group work with trained facilitators, group-worthy open-ended problems to develop critical thinking and interest-based design projects to connect students to the material. Curricular development was supported by regular collaboration meetings with expert guidance on pedagogy and incorporating social justice content. Altogether, more than 1500 students were enrolled in the first-year program during the academic year. A student survey each term resulted in an average of over 900 survey responses across the three-course series. Reflections were also collected from participating faculty. This paper focuses on the adoption of promoted pedagogical principles by the faculty, and the resulting outcomes and themes from student and faculty perspectives.

Student survey responses show the Engineering+ Program promoted engineering as a collaborative and inclusive discipline, building student skills and connections with the discipline. The students reported that their skills in problem solving, teamwork, communication, algorithmic thinking, engineering design and computer literacy were improved. Many of these skills were perceived to increase during the year in the three-course series. Encouragingly, 93% students reported that they felt like they “belonged” in the College of Engineering by strongly or somewhat agreeing with the statement.

A robust network of faculty collaboration was essential to implementing the Engineering+ Program and implementing large structural changes. Over a thousand students worked together in teams, and survey responses showed appreciation for learning those skills. Student data indicated that the semantics instructors use in the classroom are vitally important in aiding students to identify the new skills they are learning and why they are learning them, whether teamwork, algorithmic thinking or problem solving. Addressing the integrated social aspects of engineering problems, although sometimes difficult, helped students develop motivating connections between themselves and their work as students and engineers. These results and conclusion were applied to the next year’s implementation to increase consistency for students and further support their success. Broader lessons in applying complex pedagogical approaches across diverse faculty and students are transferable to other similar programs.

Introduction and Context

In this evidence-based practice paper, the reimagined first-year experience at Oregon State University for engineering and computer science students is discussed and analyzed. First implemented during the 2021-2022 academic year, the new Engineering+ Program (ENGR+) is innovative because it was designed to holistically support students as engineers (through redesigned curricula and through co-curricular events), community members (through engineering relevant social justice content), and students (through team-based design projects matching student interests to interdisciplinary technical themes).

Description of Program

In 2016, Oregon State University set the university goals to increase first-year retention of the College of Engineering's undergraduates from 84% to 90% and increase the six-year graduation from 63% to 70%. At that time, the students who started in the College of Engineering (COE) had a first-year retention rate of 88% and a six-year graduation rate of 66%. A small committee with representatives from across college units and positions (faculty, instructors, advisors and leaders) worked to review data and to identify the challenges that led to the current statistics. Challenges identified included: use of the *pro-school* model where students had to apply and be admitted to the *professional school* (in a COE specific discipline) at the end of their 2nd year; limited first-year engineering courses thus reducing COE engagement, lack of knowledge about the broad range of engineering disciplines available in COE, and finally difficulties in transferring between majors within COE. It is important to point out that while improving the numbers (to meet the University's goals) was important, the committee was focused on making recommendations to holistically change the first-year student experience. To respond to these challenges, the college leadership team developed a three Phase curricular revision plan:

- Phase I: move from pro-school to a continuous progression model; *pro-school was phased out in AY19*.
- Phase II: develop a First Year Engineering Experience (FYEE) directed at improving first-year retention and laying the groundwork for improved six-year graduation rates; FYEE was piloted AY21, and fully implemented in AY22.
- Phase III: restructure curricula in all programs to leverage the earlier engineering knowledge development afforded by FYEE and the removal of the pro-school gate; FY22 and beyond.

To accomplish the goals above, an FYEE Taskforce was created in AY19 to further investigate the challenges and opportunities afforded by a redesign of the first year. The FYEE Taskforce was composed of faculty and advisors from across the college and led by the Associate Dean for Undergraduate Programs. Part of the development process was research on comparison engineering first-year programs at other Universities. Among the main considerations were pro-school models, if college-wide first year programs existed, length of those programs, any additional requirements for common courses such as math, physics, and social sciences, grade requirements, and major selection timeline. Many Universities have published educational research on their programs, such as Arizona State University [1], [2], Texas A&M [3], and Virginia Tech [4], [5], and the Taskforce synthesized this literature into a set of recommendations for the new program. The Taskforce's recommendations were similar in content to the conclusions of ABET's 2017 report titled "Engineering Change: Lessons from Leaders on Modernizing Higher Education Engineering Curriculum" [6]. This paper does not attempt to discuss the entirety of the background work in the creation of the program's goals and structure, but rather outlines them to explain the design of the program under study. The final recommendations outlined from the Taskforce and Committee work are briefly summarized here. It was recommended that our first-year program should:

- Support students in major exploration, and freer movement between majors to increase retention and graduation metrics.
- Support student communities and sense of belonging, as they strongly affect their wellbeing and academic success, and inclusive, diverse communities lead to better outcomes.
- Emphasize engineering identity, professional development and community-building more holistically through curricular and extracurricular events
- Promote and facilitate major exploration and major switching in the first year with little or no penalty, while also accommodating those students who are certain of their major selection.
- Investigate, prioritize and implement structures, policies and practices over multiple years of assessment and reflection.
- Create a 3-course sequence (ENGR 100, 102 and 103) to replace unit specific engineering orientations and add [*Course Redacted*] as a new course using a lecture/studio model. Focus these on three main areas:
    - ENGR 100 – Engineering Orientation
    - ENGR 102 – Design and Problem Solving
    - ENGR103 - Engineering Computation

Program Development

The curricula development was undertaken starting Spring 2020 with a small group of faculty to deliver the pilot implementation during academic year 2020-2021. The three courses were designed to introduce students to engineering by scaffolding fundamental skills, connecting students to university resources and building interpersonal connections and sense of community. While each instructor can only bring their perspective to the content; the blurring of disciplinary lines is encouraged to help students develop identities as engineers regardless of disciplinary interest [6].

At least a term before each class was delivered, the participating faculty (~14 instructors for each course) developed the curricula together guided by the common course learning outcomes for each course in the series based on lessons learned from the pilot offering. Curricular development was supported by regular collaboration meetings with expert guidance on pedagogy and incorporating social justice content. Pedagogical principles, such as small-group work with trained facilitators, group-worthy open-ended problems to develop critical thinking, and interest-based design projects to connect students to the material, were used as guiding principles, along with shared course learning outcomes. Several training opportunities for faculty were available including workshops on incorporation of social justice connections, aiming to shift the focus of course content to address engineering work as sociotechnical as opposed to solely technical. Sociotechnical problem solving is a phrase coined by Leydens & Lucena [7] to describe the fundamentally social and technical nature of engineering problems, as contrasted with the purely technical focus of much of engineering education.

The ongoing trainings, community meetings, co-curricular events and pedagogical developments were implemented through a collaboration between the academic units and College-level administration. The GTAs and ULAs assisting faculty with the courses completed an orientation and training above and beyond standard training provided for teaching assistants by the College and University. This training aimed to orient them to the program, its goals, and best practices for interacting with undergraduate students.

After the pilot year, the program was fully implemented across the entire College during academic year 2021-2022. This included co-curricular components and community supports in the form of graduate teaching assistant (GTA) and undergraduate learning assistant (ULA) training. The full roll-out involved a coordinated effort of over 40 faculty with staff support across the College. A total of 74 sections were offered with a total enrollment of 5,433 students (Table 1). The courses were delivered as in-person, on-campus (on two separate campuses), and online modalities. Each course was structured to include two 1-hour lecture periods of approximately 100 students and a 2-hour studio period of approximately 25 students where they work on open-ended problems in small groups. Co-curricular events had in-person and virtual offerings with topics that drew on expertise from alumni in industry and government as professional development to advance student career readiness.

Table 1. Section Offerings and Enrollment in the Engineering+ Course Series for Academic Year 21-22 (AY22).

	ENGR 100		ENGR 102		ENGR 103	
AY 2022	**Sections**	**Students**	**Sections**	**Students**	**Sections**	**Students**
Fall 2021	21	1520	1	100	0	0
Winter 2022	4	259	18	1536	2	103
Spring 2022	1	68	4	250	16	1331
Summer 2022	2	87	2	82	3	97
Total	28	1934	25	1968	21	1531

Purpose

The purpose of this paper is to assess the initial implementation of the Engineering+ program in sufficient context to generate transferable insights, lessons learned and recommendations. We used survey data on student experiences to investigate whether and how the program met its goals.

Survey Materials and Methods

The results of the full roll-out implementation were evaluated by the course instructors, GTAs, ULAs, and other parties. To assess the student experience and program, a student survey was administered at the end of each term. This "post-survey" resulted in 893, 868, and 1033 valid survey responses over the three terms of the academic year (Fall, Winter and Spring) with an average response rate of 59%. The highest response rate was 74% during Spring 2023, and the majority of the analysis focuses on this data. Faculty assigned the survey to students with participation or extra credit (requested, not required), and many gave in-class time for completion in the last week of class.

The survey was developed by faculty leading curricular efforts in Engineering+ and included those with expertise in engineering education research. The post-survey from Fall was amended to add questions for Winter and Spring terms based on faculty input. Therefore, this analysis focuses on questions that were asked all three terms, and qualitative analysis of open-ended responses from Spring term.

The main goals of the survey were to assess impacts of the program and program elements with emphasis on student experiences and reflections. Specifically, how they were feeling about being an engineer, belonging in engineering, their intended major, and whether they were learning the foundational skills we were emphasizing (problem-solving, teamwork, communication, basic computer literacy). Less formal assessments from before the Engineering+ Program had shown stark differences in student preparation/familiarity with spreadsheets and basic computer skills. Figure 1 shows examples of the survey questions.

- Likert Scale
  - My experience in [*course name*] **this quarter:**
    - helped me learn about communication skills
    - improved my computer literacy
    - improved my problem-solving skills
    - helped me understand the engineering design process
    - gave me skills to help me succeed in other courses
    - made me aware of opportunities at OSU
    - encouraged me to meet other students and make connections.
  - I feel like I belong in the College of Engineering community.
  - I feel that my identity and background are represented within the College of Engineering.
- Multiple-choice
  - How interested were you in learning the content in this course?
  - After completing the ENGR+ courses, are you more enthusiastic about engineering in general than before?
- Essay Response
  - Give an example of an experience in [*course name*] or Engineering+ that positively or negatively impacted your feelings, sense of belonging, or being valued within the College of Engineering this quarter?
  - Why are you or aren't you more enthusiastic about engineering?

Figure 1: Example questions from student experience post-term survey, Spring 2022. The [*course name*] field is automatically filled based on the respondent's previous response.

Analysis

The survey was constructed within a theoretical framing that guides and limits the types of suitable analyses. Drawing from the authors' previous work in conceptual change research [8] the analysis of the survey responses assumes that: students' responses are representative of authentic effort to make themselves understood [9]; the meaning made during interviews exists in a richly contextualized social interaction between interrogator and respondent [10], such that responses can usefully be used to understand the socially mediated knowledge shared in a social setting [11].

Student response data was filtered for unusable responses (blanks, tests and duplicates), then analyzed collectively. Student responses to Likert and multiple-choice questions were summarized and quantified based on the total number of responses. The strongly and somewhat agree responses were grouped in summaries as "agreed." The strongly and somewhat disagree responses were grouped in summaries as "disagreed." Note that this survey was not designed or implemented to support statistical analyses of differences. Our results are therefore limited to describing and identifying trends in the content of student responses in aggregate.

Student open-ended responses were collected and analyzed using basic inductive coding in a spreadsheet. Throughout the process, the analysts collected notes and analysis memos as well as highlighting particularly eloquent or illustrative student quotes for potential use as examples. Each phase or new theme was checked against the full data set through repeating the analysis cycle from the beginning [12]. Following Braun & Clarke's method of thematic analysis [13], the first pass-through of the data used direct labelling of content or circumstance (e.g. which question they were responding to or which activities they mentioned). The second pass collected those labels into categories based on similarities in the content (e.g. student experiences of identity, how they connected class activities to broader career/identity, course topics and experiences). Responses that did not fit into our proposed categories were noted and collected. This phase also included an iterative process of displaying the data in different ways, for example sorting by code to directly compare similar student responses or using bar charts to compare the relative prominence of each code and label. This process of quantifying and summarizing blends into the final analysis phase where specific Results and Discussion points were tested against the data. At this stage, we sought out counter examples and re-examined student responses that were uncategorized.

Results

Student survey responses show the Engineering+ Program promoted engineering as a collaborative and inclusive discipline, building student skills and connections with the discipline. The students reported that their skills in problem solving, teamwork, communication, algorithmic thinking, engineering design and computer literacy were improved (Figure 2).

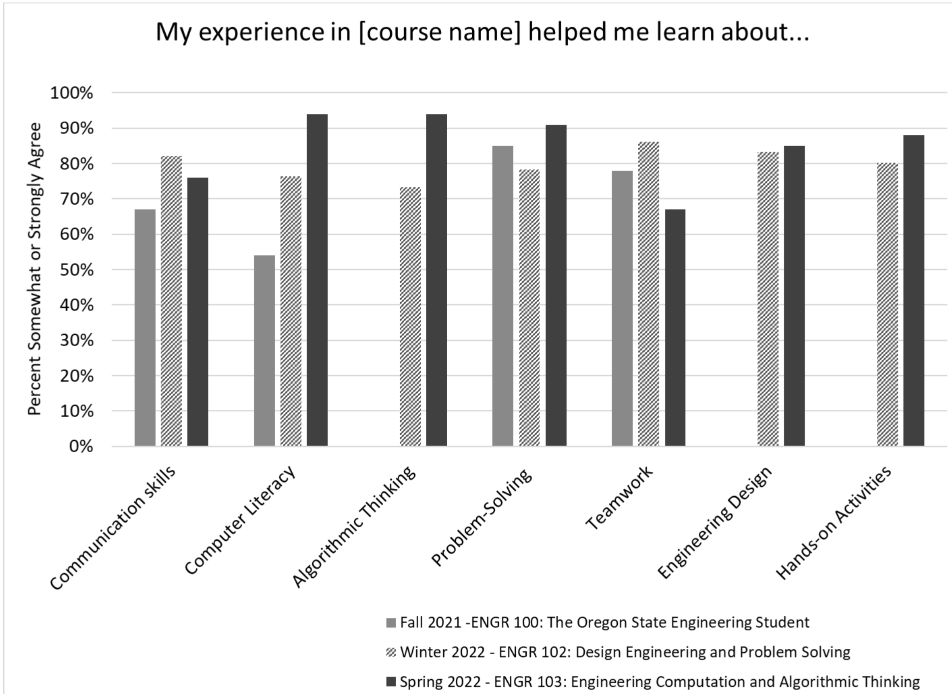

Figure 2. Student responses which "strongly agree" or "somewhat agree" that their experience in Engineering+ courses helped them learn about specific topics. Likert scale question data from Fall 2021, Winter 2022 and Spring 2022.

Some of the differences between Fall, Winter and Spring as shown in Figure 2 can be explained by which course most students were currently enrolled. Most students were enrolled in ENGR 100 in Fall, with an emphasis on career-exploration, socially just teamwork, university involvement, and included hands-on activities (for on campus courses). In Winter, the majority of students were enrolled in ENGR 102, which focused on engineering design, teamwork and problem-solving. In Spring, all students responding to the survey were enrolled in ENGR 103, which focused on algorithmic thinking and computer programming. There was a promising general trend of students reporting more skills as they advance through the program particularly in "computer literacy" (a jump from nearly 50% agree to almost 95% agree), "algorithmic thinking", and "problem-solving". An important break from this trend was the drop in "communication skills" and "teamwork" in the Spring term. These skills, along with problem-solving and engineering fundamentals were interwoven through all three courses in all three terms. However, there were not course learning outcomes specific to teamwork or communication in the programming class, beyond mention of building a resume or digital portfolio. The CLOs may need to be specifically revised to promote student awareness and practice of communication and teamwork through computation.

The skills listed in Figure 2 were emphasized during the ideation and development of these courses, and the survey results suggest that they were also communicated to most students. Note that we are not examining student competency here, but rather focusing on their experience of the program. These data establish a meaningful baseline by showing that most students saw a strong connection between the Engineering+ coursework and the key skills emphasized by the curriculum designers. Additionally, in Fall, Winter and Spring, 66%, 78% and 87% of students respectively agreed with the statement "my experience this quarter in [*course*] gave me skills to help me succeed in other courses". This is a significant finding because it shows high understanding among students of a programmatic goal that was not specifically emphasized in any one course. Note that these assessments are all averaged across multiple sections of the course with different content, structures, instructors and policies. Building from the baselines set in this preliminary study of outcomes, future work will need to more carefully investigate differences across students and courses to ensure program outcomes are being achieved equitably.

The short-essay responses highlight the very strong interrelatedness of student "interest" and "skills." One student wrote, "I think creating things is super interesting and I really enjoy doing it and learning about it. and this class helped me learn more about engineering behind computer programs and understanding computer language." This quote captures the very prominent trend of students' reporting their experiences in terms of the motivations and interests they developed *before* enrolling in college. For this large group of students (~20% of respondents), the Engineering+ program supplied skills and understandings that helped them relate to engineering more and more positively. Many students explained that their increased understanding made engineering careers more plausible to them, for example "I think that previously I was very afraid of coding and it seemed like kind of a large part of engineering and now that I understand some of the basics I'm less intimidated and more enthusiastic." One student proposed a clear connection between skills, reward and persistence, writing, "I am more enthusiastic because through these engineering courses I have become a better problem solver and I want to keep experiencing that feeling throughout my career."

Student data indicated that the semantics instructors use in the classroom are vitally important in aiding students to identify the new skills they are learning and why they are learning them, whether teamwork, algorithmic thinking or problem solving. This was most evident in our data with respect to problem solving skills (Figure 2). The second course in our series is titled "Design Engineering and Problem Solving," but we saw a dip of 7 to 13% in the student survey responses who agreed with the statement: "My experience in [*course name*] this quarter improved my problem-solving skills." Reflection by the faculty determined they need to deliberately use the term "problem solving" to describe course activities and assignments.

In total, 62% of students responded that they were more enthusiastic about engineering in general than before Engineering+ courses. The greatest theme in the short-essay responses to the question: "Why are you or aren't you more enthusiastic about engineering?" was the students' understanding of their options in engineering were expanded after the Engineering+ courses. For example: "I was worried I wouldn't be able to succeed in STEM since I'm an ex-humanities major, but I feel pretty good about my future now!" And: "It made me excited to see the type of things I will get to see in the future within engineering and added another tool under my belt for that future."

Many students appreciated the way the programming course showed the ways that computer science intersected with other engineering disciplines. For example: "I have learned so much in this class and am learning about so many different sections within an engineering project. Seeing what we can do with coding has furthered my interest in being an engineer." And: "The homework assignments had vastly different real-world applications embedded within them so I got to experience a lot of how programming can be applied to real world situations." Responses indicated this awareness was broad among the population regardless of major interest: "I mean python doesn't really appeal to my major, but I will probably end up using it in some capacity in my future."

Counterexamples from students support the same basic finding that skills and interest coevolve through education. One student stated very clearly, "I did not enjoy the ENGR+ courses as a transfer student. I felt that they were heavily geared towards first year students who don't know what they want their future career to be. I already knew what I wanted to do before taking these courses, so a lot of the work felt like busywork." Similarly, another student wrote, "...while it did a great job introducing us to different engineering majors, the only engineering major I'm interested in in computer science, and that was the case both before and after the courses. For me, these courses didn't help, as the content covered was content I'd already learned (I've been using excel, python, c++ etc for years.)" In both these cases, students did not see value in the practicing the skills themselves, but did not question their fundamental value.

Encouragingly, the student responses on community and belonging were overwhelmingly positive (Figure 3). Over the year, 93% students reported that they felt like they "belonged" in the College of Engineering by strongly or somewhat agreeing with the statement. Although we do not have directly comparable data from the same academic year from our institution, this aligns well with the long-standing first-year retention rates of approximately 80% across engineering programs [14]. The short-essay responses highlight some features of the program that supported students' senses of belonging. The students in this study reported that interactions with their fellow students led to increased belonging, confidence and motivation. For example, "During, the first group assignment I was able to talk with my group members on Teams, and it was a really positive experience listening to everyone's backgrounds in comp sci. Some had pretty extensive backgrounds; while others were completely new to it all. And so, we were able to give each other resources," and "Connecting with classmates and helping each other in studios or with assignments has helped me feel like I belong. A lot of us are pretty similar in the way we think about things so it was fun working together." Note that these two quotes show that both student differences and commonalities can be fuel for increased engagement and belonging.

References to instructors and graduate student teaching assistants were almost unanimously positive, emphasizing instructor enthusiasm and approachability as significantly influential. A small but significant portion of students reported that seeing themselves represented in the teaching staff was particularly helpful. For example, "As a woman in engineering having TAs who are also women make me feel like I belong here more than I did previously," and "There were a few Latino TA's and it made me feel like I belonged in this course."

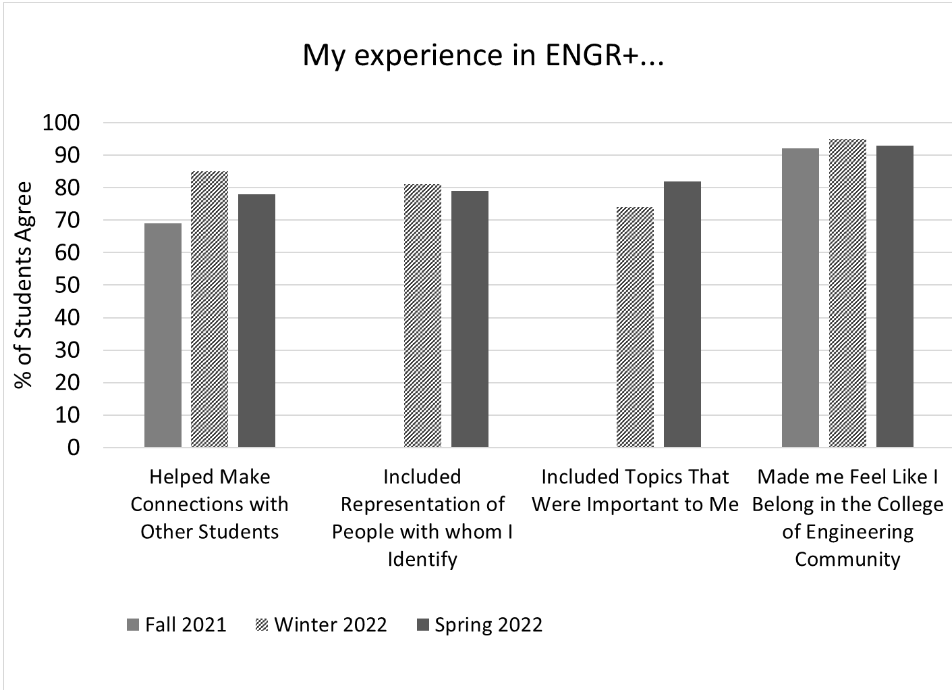

Figure 3: Survey responses either "strongly agree" or "somewhat agree" to their experience in Engineering+ courses enhancing student connections, belonging in engineering and representation. Likert Scale question data from Fall 2021, Winter 2022 and Spring 2022.

Over a thousand students worked together in teams, and survey responses showed appreciation for learning those skills with 78%, 86% and 67% of student responses somewhat or strongly agreeing with their Engineering+ course helping them learn about teamwork (Figure 2). In addition, many students mentioned teamwork often in their open-ended responses related to belonging. For example: "By working in studios and having students helping each other, it creates a sense of community and helps our peers succeed." And: "I was able to communicate with students around me, and talking with them about their courses and experiences really made me feel included in the community". We also noticed this result for the Ecampus versions of our courses: "I really enjoyed the discussion boards in this class. My classmates were very interactive and responsive to questions and I feel that everyone worked together to solve any issues that we had." This indicated the studio design of smaller group work not only allowed in-depth discussion into course content, but also enhanced the learning experience by creating connections between students.

Students also frequently mentioned that working with others enhanced their experience and their understanding of course content: "Since I had no background in engineering during my studio I would need a lot of help. One of my classmates decided to take on the role of helping me out which was awesome, I truly do appreciate what he did for me because he really helped me understand the course a lot more than I would have." Another example is: "In studio i was struggling with some coding and the person next to me was also struggling so we worked together and we are able to figure out how to do it together. This positively affected my feelings about engineering 103 because i know there is always someone in the same boat as me and there is always someone who can help."

The student response data indicated that representation, through course content, teaching assistants or instructors was important for their sense of belonging. In addition, the co-curricular events also had an enhancing effect on student's belonging: "I liked the co-curricular activities where a panel of engineers was interviewed. I liked how the people chosen to be on the panel represented many different identities, and there was a person on the panel that was similar to me. It made me feel like I could belong in the engineering community by seeing others who are like me in it."

Belonging was clearly enhanced by incorporating social justice topics and critical thinking skills into Engineering+ course content. Students noted that these elements enhanced their experience in a positive way: "Discussed equity biases in programs made by students in the class; positive experience." Many responses noted how it also increased their belonging in the discipline. "Having articles to read that revolve around social justice and equity in the engineering field was really refreshing and made me feel more included. Although there weren't any articles on LGBT issues, I felt strongly connected to some of the other articles presented and it really made me feel like OSU wants people to see the issues minorities are facing in the career world and beyond." Specifically, when the faculty discussed these topics, the students noticed: "[Instructor's first name]'s lectures about inclusivity and adapting to new people made me feel really comfortable in the class"

Students that reported dissatisfaction with the Engineering+ coursework also reported high belonging in the engineering community. Some transfer students, for example, wrote that previous life experience had prepared them for engineering careers and that the Engineering+ program was therefore not relevant or helpful for them. Similarly, some students who strongly identified with a specific career or discipline felt that the time spent exploring and building connections to broad engineering careers was wasted for them. For example, "The engineering 100 series I felt were a waste of my time. As an older student who has already achieved a degree and has gone through a lot in life, I already knew what I wanted to do, and this series extended my time in school by a year which is frustrating especially with the classes covering 'how to be an adult and successful'. I feel this is great for new students however taking older students and essentially telling them that they don't know how to be successful in life or school is a huge slap in the face." It is important to note the difference between these students' frustration and their identities as engineers.

Instructors determined many improvements and lessons learned from their experience through group and asynchronous reflections. The course structure of larger student numbers (maximum of 120) in lectures worked well for larger bulk communications and smaller student numbers (max of 30) in studio sections worked well for collaborative work, hands-on activities and teamwork practice. Some other structural successes were the project focus of each course, having different technical themes for each course section, and encouraging experienced instructors to teach the courses. The primary challenges expressed by faculty were supporting students with teaming and the relative challenges of incorporating social justice content.

Discussion and Recommendations

We highlight two implications from the Results reported above and include with each a recommendation transferable to first-year programs with similar goals and populations.

Content Skills are Co-constitutive with Career Attitudes

When asked about the sources of their enthusiasm or lack of enthusiasm for engineering, more than three-quarters of the student responses referenced an inherent, non-academic interest in the subject matter of “engineering” or “computer science.” Many students explained that their interest pre-dated their enrollment, and continues to motivate them in ongoing coursework. Similarly, the student responses explaining a lack of enthusiasm also predominately referred to a lack of inherent interest in the subject matter of engineering. In both cases students did not differentiate strongly between the (a) the subject matter of Engineering+ courses, (b) the content of other science and math courses, (c) engineering as a professional career trajectory, instead referring (perhaps as led by the survey wording) to discuss all three things under the label of “engineering.”

An educator’s first impulse might be to “fix” students’ thinking to help them better understand their education, careers and skills with more nuance. However, these results remind us that students are using their thinking as they are developing it. We don’t want to tell students they are “wrong” about engineering careers or disciplines if they are feeling a strong, motivating connection. These students are building, revising and rebuilding tenuous connections between interacting ideas: there is a complex co-development of the concept of engineering, their sense of self, their assessments of themselves and their skills, and their academic and career plans.

We recommend, therefore, that similar programs seek to build on students’ existing connections while refining them, instead of trying to replace them or seeking conformity and consistency. Building on suggestions in the student responses, we recommend using interdisciplinary engineering projects to help students draw connections between their growing skills, their interests and their career possibilities. A prescriptive approach where faculty and students worry about aligning students into the “correct” discipline can discourage students and disempower students. An exploration of applied interdisciplinary projects could help each student find their own connections without suggesting that some degree choices or career aspirations are most desirable.

Under the same logic we recommend increasing the broad inclusivity of student belonging efforts by explicitly integrating social justice to engineering content. Student responses showed how seeing themselves represented in their engineering classes and coursework helped students engage with the material and maintain motivation. The long-term project of changing the demographics of engineering education and practice is important ongoing work, but inherently slow and incremental, so “representation” in that literal sense has limited value for many institutions. However, as we have demonstrated, students can also see themselves represented in engineering through the pedagogical use of sociotechnical problem solving and diverse course content. Teaching engineering skills through sociotechnical problem solving would both increase the skills of graduates and increase the opportunities for diverse students to see themselves as engineers.

Structural Alignment Makes Space for Diverse Consistency

A robust network of faculty collaboration was essential to implementing the curricula and unifying the student experience without having a rigid course that treats all subjects and students as the same. Faculty built on their own interests from sewage to space travel, and although all sections of each course had the same course learning objectives, the faculty sought to achieve them in diverse ways. This diversity was a strength, and the consistency of student responses about their skills and belonging indicate that common elements were sufficient to achieve the shared goals.

We recommend seeking consistent outcomes without requiring conformity by utilizing shared institutional structures and aligning priorities and purposes. Educational discourse and research literature often emphasize practices over purposes, asking questions about how best to achieve certain goals or comparing activities or behaviors based on educational outcomes. Engineering faculty often operate under vastly different assumptions about the purposes and priorities of education, however, and these fundamental differences affect each of the countless smaller decisions that result in choosing one practice over another. Achieving consistent outcomes through consistent practices requires conformity in an overwhelming number of influential course components (e.g. grading polices and rubrics, assignment details, communication styles, materials, media). Perhaps the most influential component of a course is the relationship between instructor and students, which is inherently idiosyncratic. Developing, defining and reiterating a set of priorities and purposes may achieve more consistent outcomes by allowing faculty to use their preferred practices, utilizing their strengths and preferences to achieve shared program goals.

Iterative Improvement and Next Steps

These results and conclusion were applied to the next year's implementation to increase consistency for students and further support their success. This included reviewing student survey responses and instructor reflections by the next cohort of instructors (most were returning instructors).

Broader lessons in applying complex pedagogical approaches across diverse faculty and students are transferable to many similar programs. Not surprisingly, communication is key. Structuring the program with distinct curricular leads for each course has been valuable for easing the lift of faculty curricular development, and for adding depth and consistency to the curricula. Probably most importantly, this structure has allowed faculty to practice inclusive teaming practices themselves as they work through curriculum development. Remarkably, the arduous process of having 13 faculty of varying disciplines, backgrounds and expertise develop a course together created a sense of comradery and mutual respect despite differences of opinion on some elements. Overall, the reflection and analysis process reinforced the motivation to work with assessment experts in developing our surveys and assessment metrics, and that work is ongoing. Formal assessment discussions are in progress.

Limitations

We have limited our recommendations and interpretations based on the limitations of our study design and methods. The primary limitation is that student's choices to respond or not respond are very likely influenced by their sense of belonging and general affect around the Engineering+ program. Although we do not have evidence of any selection bias, and the response rates are relatively high, it is still important to note that our data collection may have underrepresented students experiencing a lack of belonging and disconnection with the program. Our approach of analyzing student responses in aggregate also has the potential of reifying existing inequities. Research has shown that when education researchers ignore identity and demographics (e.g. race, gender, ethnicity) in our work, it has a disproportionately negative impact on nondominant identities because it tacitly centers exclusive and oppressive norms and assumptions. Future work will need to reassess these findings explicitly in the context of how student experiences vary by identity.

Conclusion

The authors of this paper were faculty, administrators and students involved in the Engineering+ program, and as such we are heartened by these findings. Implementing this new first year program was an enormous, complex task. The general results showed that students gained valuable skills and a strong sense of belonging in our College. Students' praise for each other, their instructors, the undergraduate learning assistants, and the graduate teaching assistants was particularly satisfying, because it matched our student-centered priorities, and our framing assumptions that the best learning and engineering happens in healthy communities. We acknowledge that there is still much work to continuously improve and adapt our program to meet the diverse needs of our students, and we are committed to this effort.

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