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Board 351: Preparing Early Engineers Through Context, Connections, and Community

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Preparing Early Engineers through Context, Connections, and Community

Abstract

This NSF-IUSE project began in fall 2022 and features cross-disciplinary collaboration between faculty in engineering, math, history, English, and physics to design, pilot, and assess a new learning community approach to welcome precalculus level students into an engineering transfer degree program. The learning community spans two academic quarters and includes six different courses. The place-based curriculum includes contextualized precalculus and English composition, Pacific Northwest history, orientation to the engineering profession, and introductory skills such as problem-solving, computer programming, and team-based design. The program also features community-engaged project-based learning in the first quarter and a course-based undergraduate research experience in the second quarter, both with an overarching theme of energy and water resources. The approach leverages multiple high-impact educational practices to promote deep conceptual learning, motivate foundational skill development, explore social relevance and connection, and ultimately seeks to strengthen our students' engineering identity, sense of belonging, and general academic preparation for success in an engineering major.

Fall 2023 marked the first quarter of piloting the new learning community with a cohort of 19 students out of a capacity limit of 24. This paper reports on the demographics of the first cohort and compares them to enrollment in a parallel section of our Introduction to Engineering course that is not linked. We also share some of the students' reasons for enrolling and their feedback on the experience. We found that students in populations with intensive entry advising such as International Programs and Running Start (a high school dual-enrollment program) appear to be overrepresented in the first cohort. This finding correlates with a theme in nearly all student responses that they learned about the program through advising. Finally, we describe some example activities and student projects that illustrate how the curriculum design integrates content across the academic disciplines involved.

Introduction

The PEEC^3 (Preparing Early Engineers through Context, Community and Connections) project is in the second year of a five-year grant from the NSF IUSE: Innovation in Two-Year College STEM Education (ITYC) Program [1]. The main goal of the project is to develop, pilot and assess a two-quarter long team-taught learning community for engineering students at Whatcom Community College (WCC) who start at the intermediate algebra or precalculus math level. The learning community, titled "Engineering in Context" spans two academic quarters and includes six different courses which integrate place-based learning. The curriculum includes a new two-quarter precalculus for engineering sequence, contextualized English composition, and Pacific Northwest history. Specific sections of these four courses along with our existing first-year engineering sequence (ENGR 101: Introduction to Engineering and ENGR 151: Introductory Design and Computing) create the two-quarter learning community. Introductory engineering content includes an orientation to the engineering profession, academic skill development, introductory physics, problem-solving, computer programming, and team-based design. The program also features community-engaged project-based learning in the first quarter and a course-based undergraduate research experience (CURE) in the second quarter, both with an overarching theme of energy and water resources. The approach leverages multiple high-impact educational practices to promote deep conceptual learning, motivate foundational skill development, explore social relevance and connection, and ultimately seeks to strengthen our students' engineering identity, sense of belonging, and general academic preparation for success in an engineering major.

Year 1 work focused on developing the faculty team and high-level visioning for the student experience and curriculum using the backward design framework [2]. We presented the results of year 1 work, the background and theoretical underpinning and motivation for the project, and our research and assessment plan in 2023 [3]. This current paper reflects on our experience recruiting and piloting the learning community courses for the first time in Fall 2023 and Winter 2024. We present the demographics of the first cohort in comparison to students in a non-linked version of our Introduction to Engineering course (ENGR 101). We also describe a few examples of interdisciplinary curriculum and projects that we have developed and share some student feedback on their experience.

Student Recruitment, Demographics, and Retention

We took the following steps to recruit students for the new learning community. A new page on the college website provides information about the opportunity and potential benefits to students [4]. Our engineering advising and outreach specialist targeted recruitment by emailing local high school counselors and attending local community and high school events to promote the opportunity. They also contacted students enrolled in the non-linked ENGR 101 section who appeared to be a good fit for the learning community based on math placement and other courses in which they were enrolled. The college marketing office placed a full-page advertisement on the back page of the *Fall 2023 Playbook*, published by the City of Bellingham Parks and Recreation Department, that compiles information about community programs and events. This publication has wide distribution in the WCC service area, including all high school guidance counselors.

Students also had material incentives to enroll. As described in [3], the learning community students can reduce students' tuition expenses by accelerating their progression through prerequisite courses by up to ten credits (one physics and one math course) depending on their initial preparation level. Grant funding pays for all student lab fees and course supplies, reducing the cost of attendance. Lastly, enrolled students receive up to $200 in stipends for participation in the research components of the project (i.e. surveys, interviews, and focus groups).

Census day enrollment of the first cohort in the Engineering in Context Learning Community was 19 students out of a capacity of 24. This compares to 22 students enrolled in the non-linked Introduction to Engineering (ENGR 101) section (also 24 capacity). Table 1 below summarizes the demographics of these two courses. "Running Start" refers to a dual-enrollment program in which local high school students can enroll in WCC courses at minimal cost and earn college credit that also applies toward their high school graduation requirements.

Table 1. Demographics of the inaugural Engineering in Context Learning Community cohort.

	Non-linked ENGR 101	**Engineering in Context LC**
Census Day Enrollment	22	19
Gender		
- Female	6	2
- Male	13	17
- Unknown	3	0
Race/Ethnicity		
- HUSOC*	5	2
- Not HUSOC	15	11
- Not reported	2	6
Age		
- Under 18	3	9
- 18-19	10	4
- 20-23	7	2
- Over 23	2	4
Running Start	3	5
International	1	5
1st Term at WCC	8	17

*HUSOC = Historically Underserved Students of Color

The first thing we note is that the total Fall 23 ENGR 101 enrollment of 41 students is a 20% increase compared to Fall 22, outpacing broader college enrollment growth of 6.5% fall-to-fall. This increase may indicate that marketing of the new entry pathway was successful at drawing increased interest in the WCC engineering program in general, even if some prospective students wound up enrolling in the non-linked ENGR 101 option. Most of the learning community students were in their first quarter at WCC, while the non-linked ENGR 101 drew more from existing students.

While the overall numbers are too small to draw any firm conclusions, there are a few differences between these two cohorts of students that stand out. Running Start and International program students make up over half of the enrollment in the learning community, but less than 20% of the non-linked section. This overrepresentation of these two populations (much higher than collegewide or historical ENGR 101 data) also leads to a substantially younger cohort. We think there are two primary reasons for this pattern. First, the Engineering in Context program required enrollment in a full-time course load (15 quarter credits) of all three learning community courses meeting MTTh 9:30-12:20 and TTh 1:30-4:10. International and Running Start students are more likely to be enrolled full-time and less likely to have other schedule constraints (e.g. work/family commitments) that make the meeting schedule unattractive. Second, as we discuss further below, we learned that most Engineering in Context enrollees learned of the program through communication with an advisor. Running Start and International Students generally get more intensive entry advising than the general new student population at WCC.

There were fewer female-identifying students in the learning community section, but this difference (10% vs. 27%) is not out of the range of typical quarter-to-quarter variation in ENGR 101 enrollment that has varied 0% to 30% over the past 5 years.

Figure 1 compares learning community students' math preparation levels with those in the non-linked course section. Math preparation level is lower in the Engineering in Context section with 14 of the 19 students at the MATH 99 or MATH 141 level. This result was expected since the program includes a two-quarter contextualized precalculus sequence. Students placing in MATH& 142 (Precalculus 2) or higher would be stepping backwards in their math sequence to participate, as five students chose to do. In contrast, over half of the students in the non-linked course had placed into Calculus 1 or higher.

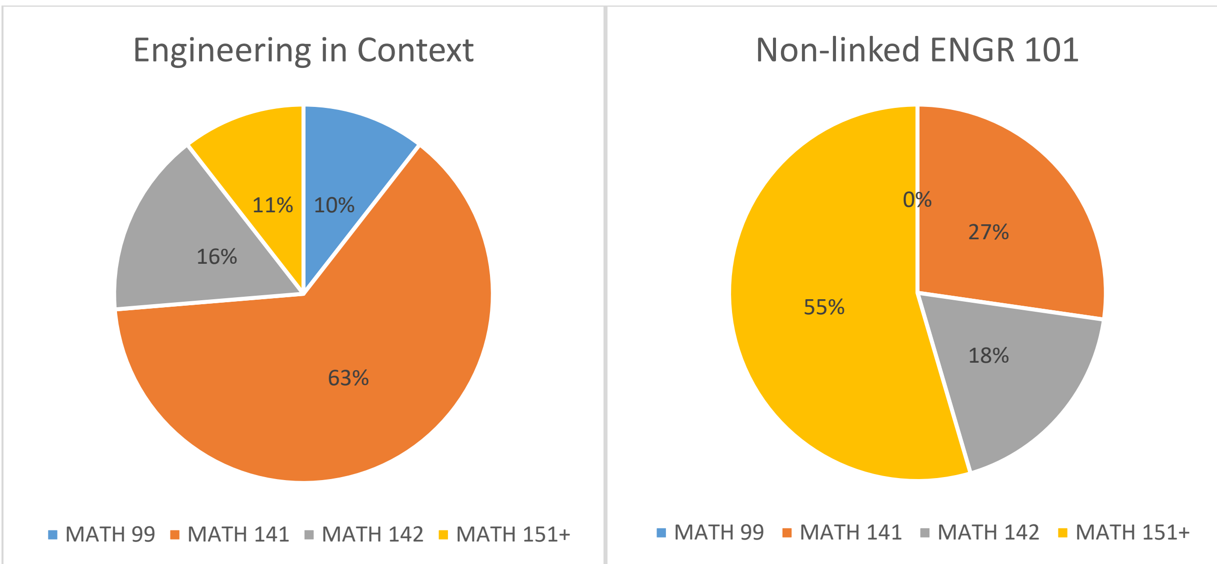

Figure 1. Comparison of math preparation levels between the Engineering in Context Learning Community students and those enrolled in the non-linked ENGR 101 section. MATH 99 = Intermediate Algebra. MATH 141 = Precalculus 1. MATH 142 = Precalculus 2. MATH 151 = Calculus 1.

Reasons for Enrollment
Students completed an entry survey during the first week of class that included the prompts: "How did you find out about this program?" and "Why did you sign up for this program?" The vast majority (15 out of 17 responses) cited advising as their source for learning about the program with responses such as "my advisor told me that there's this new engineering program that gives us many benefits." The other reasons given were:

- *I found this class by accident whilst browsing the course catalog. For a transfer degree, I needed a physical science and more math/engineering courses.*
- *I was planning to do full time at WCC, so my mom said "want to do this thing where you take classes with the same people?" and I said sure.*

In response to the second prompt, students articulated a variety of reasons for enrolling including the following:

- *I signed up for this program because it satisfies multiple prerequisites for a transfer degree and in an interesting, practical way.*
- *I signed up because they offer lots of experiences, not only I got to learn engineering but I also got to learn the history here. I know that I will gain a lot of new experiences by joining this program.*
- *It seemed like a curriculum I'd like in an environment I would like to learn in.*

Retention
Out of the 19 students enrolled in the first quarter, 18 passed all three learning community courses, and 15 continued to the second quarter LC courses in Winter 24. The one who did not pass stopped communicating at week five of fall quarter. The three others who did not continue left for various reasons. One student enrolled in Calculus 1 due to their past qualifications and is continuing to major in engineering. One student chose to major in another STEM field. One could not continue this college path due to financial reasons. None of them expressed any dissatisfaction with the learning community experience. Two of the four students who left Engineering in Context continued in their MATH progression at the college, one transitioning to MATH 142: Precalculus 2, and the other accelerating to MATH 151: Calculus 1, consistent with their initial placement. In summary 17 of 19 fall quarter learning community students enrolled in winter quarter courses and successfully progressed to their next MATH course on their respective STEM pathways.

We can contrast this result with retention and math progression outcomes in the non-linked ENGR 101 section. This ENGR 101 section also had a 95% pass rate (21 of 22 students earned a C or better). Two students, including the one who did not pass ENGR 101, did not enroll in winter quarter courses. Of the 20 remaining, 16 enrolled in their next math course in winter. Two students did not take math concurrently with ENGR 101 in fall and are not enrolled in math for winter either. One student is repeating their fall math course. The last student took MATH 141 concurrently with ENGR 101 but did not enroll in math for winter. In total, 16 out of 22 students in the non-linked ENGR 101 section successfully progressed to their next MATH course in winter.

To put these initial retention results in context we can compare them to institutional data for math success rates college wide. The 89% success rate (17 out of 19 students progressing to the next math course that is part of the learning community) compares to a college-wide success rate of 67% for MATH 99 and 77% for MATH 141 for the 22-23 academic year. We note that the math progression rate for the non-linked ENGR 101 (16 out of 22) is roughly in line with the college-wide pass rate for MATH 141 (77%) and MATH 142 (75%). These initial results for the learning community supporting math progression are quite promising, but there are significant caveats. Recall that Running Start and International Program students are overrepresented in the learning community cohort. Both populations tend to have higher math course success rates at the MATH 99/141 level compared to the general student population. Furthermore, we only have data for how the students progressed within the learning community program. Success rates in subsequent math courses after completion of the learning community will be more telling.

Example Curriculum

Here we describe a few examples of classroom activities and student projects to give a flavor of the student experience and the teaching team's efforts at contextualization and integrating content across the learning community courses.

First Quarter Final Project
The first quarter integrates Introduction to Engineering, Pacific Northwest History, and Precalculus for Engineering 1. For their final project, students compared historical photos to current ones of a site in Whatcom County, located sources in a regional archive, and documented changes to the engineered environment over time. Over the quarter, students practiced the skills of a historian -- sourcing, corroboration, and context -- so that by finals week, they were prepared to write a four-page research paper about a site in Whatcom County and present their findings visually during finals week. Alongside this work, they learned how to use laser cutters and 3D printers to add an engineering model to support their history research. The final synthesis required students to answer one of the essential questions developed for the learning community [3]: *How does the engineered world affect how we live?*

Figure 2. (Left) Student-designed model of a dam used to explore the impact on sediment from dam removal. (Right) Historical photo of the dam (photo credit: Jack Garver).

One example final project was researching the removal of a dam in the Middle Fork of the Nooksack River. The group began by using various resources to research the reason for the addition and rationale for the removal of the Middle Fork dam. While locating sources for the paper, the group used a stream table to create a mathematical model to measure the impact of sediment when damming and undamming a river. The group found a historical picture of the dam when first installed and then used a drone to capture an image after its removal. From the pictures, they created a computer-aided design (CAD) to model and 3D print the dam for use in the stream table as shown in Figure 2. They laser cut a tool to hold a phone from which they captured timelapse videos to visualize and record the dam impacts. They used a stream table to conduct multiple simulations of running water to create a river, dam the river, and then undam the river and to measure the depth of the sediment at each stage. After gathering data, they used a spreadsheet to graph the sediment heights and calculate the erosion rate.

Second Quarter

The second quarter integrates Introductory Design and Computing, English Composition, and Precalculus for Engineering 2. We are developing a series of math labs in which students explore math concepts in the context of engineering and physics applications inspired by analogous work in [5] [6]. The engineering course starts with a crash course for students in Python programming in the context of microcontroller applications. An early tutorial introduces the use of pulse-width modulated (PWM) electrical signals to produce pseudo-analog voltages to control electronic components such as light-emitting diodes (LEDs) and servo motors. We used the PWM signal as context for a math lab on periodic and piecewise functions. Students explore concepts such as frequency, period, and piecewise function notation by analyzing the PWM microcontroller output signal and an associate voltage response of a resistive-capacitive (RC) circuit connected to the pin. The lab also provides a fruitful context for students to experiment with the effect of different parameters in the piecewise exponential function that generates the sawtooth wave pattern in the RC circuit response. Figure 3 shows the oscilloscope display of an operating circuit and the accompanying Desmos model of the RC response to facilitate student exploration of the function parameters. Later math lab activities include introducing sinusoidal functions using a spring-mass-damper experimental apparatus and a series of activities with Dobot Magician robotic arms.

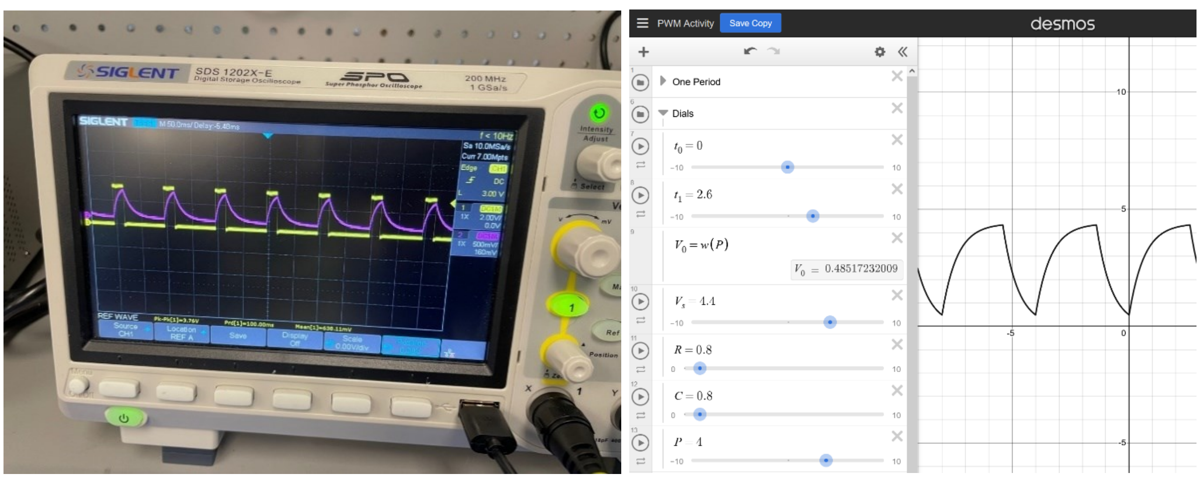

Figure 3. (Left) Example oscilloscope display students use to explore piecewise and periodic function. The yellow line is a PWM signal from a microcontroller pin. The magenta line is the response of an RC circuit connected to the pin. (Right) Desmos model students use to explore the effect of different parameters in the mathematical model of the RC circuit voltage response.

The major writing project for the English component of the second quarter is called the "Problem Exploration Project." Students start by reading and discussing a series of articles exploring the concept of sociotechnical dualism [7] [8] and considering how engineering could be more aware of the social context of their work. They pick a societal problem for which engineering has a plausible role in contributing to a solution. The paper assignment encourages a deep exploration of the social and technical aspects of the problem without prioritizing either and with explicit instruction for students to not propose a solution. Example topics chosen by the students include ocean acidification, housing affordability, and declining bee populations.

Student Feedback

The project external evaluation consultants conducted a site visit during the last third of the term that included class session observations and student focus groups. Overall student feedback on their first quarter experience to date was generally positive as illustrated by the selected student comments below.

- [Structure and Curriculum] *"I mean the curriculum's been designed to make us do as much group work as possible and it's done a good job of making you build relationships with other people in the cohort and just generally work together. The instructors try and get you to work with everyone at least a couple times and they've done a pretty good job of that.*
- [Structure and Curriculum] *"I like that there's a bunch of group projects, it helps you work with different groups of people from different backgrounds and you think differently. And I think that'll help for later in life."*
- [Meeting Schedule] *"I like to have days focused on one thing. So I have a full day of work, full day of school. So it's 9:30 to 4:10? My next day is a full eight hour shift at work. I don't like to split 'em up throughout the day. I don't want to go to school then have leave to go to work and then work. I don't like that kind of stuff. So it worked well with my school, my work."*
- [Interdisciplinarity] *"When we're working on trigonometry and a lot of our math concepts, we've then immediately gone into an engineering thing that directly utilizes those math concepts, which is great because it makes them less abstract and you can immediately see the applicability of what you're doing, which it makes it, at least for me, a lot easier to actually understand and have the desire to learn things when you can see exactly how they're going to be used. How does this apply? How do you use it?"*

Additional feedback was collected in some one-on-one interviews with students following their second quarter experience. This feedback continued the positive trend including some students' sentiments about the efforts to integrate history and English into the experience.

> *Going into the course I had the mindset of these are your humanities courses and these are your science classes and never shall the two meet, but leaving I realize they interact often and need to be aware of each other and pair well.*
>
> *This is weird for me to say, but I did actually enjoyed the history and the English portions of it quite a bit because we were also able to tie it with the engineering aspects of it. Those are two classes that I hated in high school. I almost failed high school because I failed a required history class just because I didn't want to do the work. But I actually*

found that I really enjoyed these just because they were able to make it relevant to what I was interested in.

Conclusion and Future Work

The first-year pilot of the Engineering in Context learning community has been promising. We were successful in recruiting a nearly full cohort of precalculus level students interested in engineering. Retention and math progression results appear to be improved compared to a non-linked version of our Introduction to Engineering course, but it is too early to draw any conclusions as to the effectiveness of the program. Student feedback has been generally positive with students expressing appreciation for the cohort building opportunity, project-based learning, and interdisciplinary connections the teaching team is working to emphasize.

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