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A Sustainability framework as a tool for student recruitment and retention in first year engineering

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Keyword tags: Engineering for One Planet; sustainability; engineering identity; systems thinking; survey methods; concept map

Abstract

This is a complete evidence-based practice paper. The goal of this project was to increase recruitment in a first-year general education engineering course by incorporating Engineering for One Planet curricula. We also assessed how students' engineering identity, engineering career intentions, systems thinking attitudes, and values changed during the course.

Our first-year engineering class is both a general education class for students who are interested in STEM and an introductory class for engineering majors at The University of North Carolina at Chapel Hill. One goal of this class is to recruit and retain students in our engineering major and minor. Teaching students about the role of engineering in sustainable development is an opportunity to broaden their understanding of who can be an engineer, and the sociotechnical work engineers do.

To accomplish our recruitment objective, we include technical and social sustainability content aligned with the Engineering for One Planet (EOP) Framework in our course. EOP is an instructional framework designed by educators through the American Society of Engineering Education and the Lemelson Foundation to assist in training engineering students in social and technical sustainability competencies. For example, students use systems mapping to visualize product lifecycles and use lifecycle assessment to estimate environmental impacts from those products. Our goal is that all students at our university can develop confidence using engineering tools through this sociotechnical experience of the work engineers do for human well-being.

To assess the impact of our changes to the course, we surveyed students before and after the course to measure changes in their attitudes toward systems thinking and values thinking. We also surveyed students regarding either a) their engineering identity (for students planning an engineering major) or b) their intentions to use engineering in their future work (for non-engineering majors).

In this paper, we provide a description of our course materials for sociotechnical sustainability education and analyze the results of our student surveys regarding systems thinking, values thinking, engineering identity, and career intentions before and after our course.

Introduction

We implemented learning objectives from The Engineering for One Planet framework [1] into our general education first year engineering course, *Exploring Engineering*. Our department, Applied Physical Sciences, is home to a new general engineering degree designed to draw on the strengths of The University of North Carolina at Chapel Hill, our liberal arts university. The *Exploring Engineering* course has two goals: For both engineering majors non-engineering majors, it serves as an introduction into the skills and toolsets that engineers use to solve human-centered problems. For engineering majors (30% of enrollment), the course is also intended to build professional identity and lay groundwork for skills used in future courses (ex. MATLAB programming). We used the Engineering for one Planet framework to better articulate the skillsets students gain from our course – systems thinking and values thinking. We designed the *Exploring Engineering* course to showcase a liberal arts infused vision of what engineering is and what engineers do. The course content includes biomimetic design and sustainability, which are intended to show students that some parts of engineering may not fit their preexisting stereotypes of the field.

Recruitment

Engineering programs have long grappled with high dropout rates and enrollment that does not represent their broader university. Students' motivations to enter and leave engineering programs are diverse [2], [3] and their decisions typically weigh multiple factors [4]. Students may never consider engineering because of its reputation – that it is socially isolating, disciplinarily isolated, or otherwise incompatible with their personal values [5], [6]. Students may leave engineering because they lose interest or believe they do not belong [4], [7]. Some students dissatisfied with engineering programs, in particular women, want to understand engineering through social and humanistic lenses [7], consistent with ideals like this statement on the National Society of Professional Engineers website: "*For more than a century, Professional Engineers have prioritized public health, safety, and welfare by committing themselves to the highest standards of ethics and expertise*" [8]. In other words, these students are invested in making an impact on human wellbeing.

Some research and practice suggest that faculty can make a positive impact on recruitment and retention in engineering bachelor's programs by changing course content or pedagogy [9], [10]. For example, active learning, project-based classrooms can make quantifiable improvements in student's retention in engineering [9], and course advertisements that include community contributions (i.e. service learning) can increase student interest in engineering courses [11].

Engineering and Liberal Arts

As an engineering department at a public liberal arts university, it is part of our responsibility to help educate an informed public that is equipped to understand technological developments and shape technology's place in society [12]. To that end, we recruit non-engineering students into our *Exploring Engineering* course. Our primary hope for these students is that they will grow in their capability to understand and apply the tools of engineers in future experiences. We expect that these liberal arts students expect engineering course content that is transdisciplinary, transferable [13], and well-integrated with social and humanistic perspectives [14]. This aligns closely with the preferences of some students who leave engineering described above.

The Engineering for One Planet Framework

Sustainability topics are one way to incorporate sociotechnical course content that bridges engineering and the liberal arts, which may help increase enrollment of prospective engineering students who are motivated by the human dimension of the field [15]. Engineering educators have previously used sustainability topics to recruit and retain students [16].

Participating in the ASEE-Lemelson Foundation Engineering for One Planet community of practice enabled us to help students in *Exploring Engineering* uncover engineering's connections to human and planetary wellbeing using the lenses of systems thinking and values thinking. The Engineering for One Planet framework is a systematic set of engineering sustainability learning outcomes for all engineering students [1]. Through studying the framework and participating in the community of practice, we discovered how to articulate the transdisciplinary skills we were already teaching students in *Exploring Engineering* (systems thinking and values thinking) – and how they tied into the Engineering for One Planet framework of learning outcomes. While the EOP framework was updated in April 2026, this paper references the 2025 edition.

Systems Thinking and Values Thinking

The Ways of Thinking framework, described by [17] in the context of sustainability education, describes four ways of thinking (knowledge, skillsets, and mindsets used to approach problem solving): systems thinking, values thinking, futures thinking, and strategic thinking. We recognized two of these, systems and values thinking, as already existing themes of *Exploring Engineering* which were important to our educational goals, but which we were not articulating to students. Systems thinking foregrounds the interconnections and dynamics of elements within a problem space [17], [18]. Values thinking foregrounds how ethics and norms influence decision making [18]. These two ways of thinking are excellent examples of the transdisciplinary skills that students can use to bridge engineering and liberal arts expertise.

Research Questions

After we added the Engineering for One Planet Framework to systematize our approach to teaching engineering sustainability, we wanted to learn about how our students might be changing during the course. We didn't directly measure the effect of course changes on recruitment, but we designed some indirect survey measures to solicit information that may correlate with recruitment and retention behaviors. Our research questions were:

1. How did students' attitudes toward the use of systems thinking change during *Exploring Engineering?*
2. How did students' values change during *Exploring Engineering?*
3. How did engineering majors' engineering identity change during *Exploring Engineering?*
4. How did non-engineering majors' expectations of using engineering change during *Exploring Engineering?*

Methods

We implemented several changes to *Exploring Engineering* based on the incorporation of the Engineering for One Planet framework. *Exploring Engineering* was developed as a project-based, active-learning class where students engage in open-ended problem solving to learn to apply engineering tools. Before incorporating this sustainability framework, the course consisted of three project-based modules – computer simulations, biomimicry, and sustainability – and a final project which integrated aspects of each.

Learning activities and outcomes

Starting in fall 2025, we created five new class plans linked together as an environmental impact assessment module within the course. The other two modules (MATLAB simulation and biomimicry) were also framed within the lens of systems thinking and values thinking (which were previously implicit). The relevant elements of course structure and learning outcomes are described in Table 1.

Table 1. Overview of course outcomes and activities

Module	Learning Objective	Learning Activities
-	Reflect on your changing attitudes during the course	Systems and values pre-post survey, Engineering identity pre-post survey, Use of engineering pre-post survey
Computer simulations	Design a model to inform an engineering decision by analyzing a real-world system[s]	Simulation assignments 1-3
	Implement a model in MATLAB	Simulation assignments 1-3
	Validate model results	Simulation 2
	Interpret simulation outputs to make recommendations	Simulation assignments 1-4
Biomimicry	Identify and use design strategies from nature	Biomimicry research paper, Final project
	Model natural systems to extract design ideas[s]	Biological system analysis [N]
Environmental Impact Assessment	Weigh triple bottom line tradeoffs in engineering decisions[s 1]	Simulation 4 (airborne wind tubine), Final project
	Describe product lifecycles with whole systems maps[s 2]	Whole systems mapping homework, Final project
	Recognize opportunities to solve environmental challenges[3]	Whole systems mapping homework, Final project
	Create an estimated Lifecycle Assessment (LCA) for a product[4]	LCA homework, Final project

[s] Learning objective is part of the systems thinking theme
[N] This was not included in the course in Fall 2025, but was integrated in Spring 2026+
[1] EOP systems thinking core learning objective #2 (2025 edition)
[2] EOP systems thinking advanced learning objective #3 (2025 edition)
[3] EOP environmental literacy core learning objective #1 (2025 edition)
[4] EOP environmental impact assessment core learning objective #3 (2025 edition)

The new class activities we developed to create the systems thinking throughline and the engineering sustainability module were:

> **Biological system analysis:** In this lesson, students practice implementing biomimetic design principles on a system scale, rather than an individual item or product. Students study how bees regulate their hive temperature through heating and cooling behaviors, then apply their findings to design commercial building HVAC systems.
>
> **Airborne wind turbine simulation**: For this project, students use an existing computational model provided by a "colleague" to make recommendations for the placement of an airborne wind turbine in a fictional, rural town. The turbine requires 3

anchors, and each anchoring location comes with financial, social and environmental costs which have already been quantified. Students must use the computational model to discover the optimal solution that includes both financial, environmental and social value. This activity took place after the first 3 computer simulations. It was based on [19], as presented at the "Unravelling the Value Tensions of Sustainability" KEEN faculty development workshop by Anna Howard and colleagues.

Whole systems mapping: Students are instructed in the components of a whole systems map and the use of a map to find opportunities to solve environmental challenges. Students practice making whole systems maps of everyday objects and identifying possible changes to the system.

Interpreting Lifecycle Assessment (LCA) data: Students read an LCA report, then interpret the data to make design recommendations.

Creating an LCA: Students create a variety of estimated LCAs based on a single product bill of materials, then analyze the difference in the resulting environmental impacts.

These activities prepared students to incorporate an environmental impact assessment into their final projects. In the final project, students develop a biomimetic design idea and test a low-fidelity prototype. They must refine their design idea based on takeaways from a whole systems map and estimated LCA.

Systems thinking and values thinking throughlines

In the computer simulation module, students create and report on the outcomes of three models: 1) a bike share with bikes moving between locations, 2) a skydiver's parachute, and 3) fire spreading through a forest. In simulations one and three, students investigate the dynamics of systems that change over time. They must analyze real-world systems to develop appropriate models. They must also make value-laden recommendations based on their simulation results – structure of the bike share, size of the parachute, and fire management strategies.

In the biomimicry module, students practice recognizing and abstracting design ideas from nature. Students must use values thinking to recognize opportunities and determine how to implement them. They use systems thinking to translate biological systems into abstract concepts, then implement those concepts in a non-biological way.

In the environmental impact assessment module, students use values thinking to weigh the triple bottom line tradeoffs resulting from their design recommendations. They use systems thinking to visualize product lifecycles, user interactions, and infrastructure systems – then to prototype changes to those systems.

Surveys

To assess our research questions, we used survey responses our students completed as reflection activities within *Exploring Engineering*. Each student was offered two separate inventories, both before and after the course (a total of four surveys). Our proposed surveys were reviewed by our institution's IRB and classified as "Not Human Subjects Research" because their function was to assure and improve the quality of the course, rather than to create generalizable knowledge.

To understand how our students' attitudes toward systems thinking, the role of engineering in society and their values for their work changed after *Exploring Engineering* (addressing research questions 1 and 2), we created a survey instrument asking students to rank their agreement with items related to systems thinking and to the roles and values of engineering, hereafter referred to as the systems thinking and values survey. We adapted systems thinking inventory items from [20] to suit our course context and to focus on three principles of systems thinking: interconnectedness (I), nonlinear causality (N), and controllability (C). We also added six items pertaining to the role of engineering in society and the respondent's values. Students were asked to complete this survey once at the beginning of the course and once after the course final project. In the post-survey, students were also asked two open-ended questions pertaining to their use of system thinking in the course. The full survey inventory is shown in Table 2.

Table 2. System thinking and values survey inventory

ID	Item	Construct
To what extent do you agree or disagree with the following statements? There are no right or wrong answers. 1 strongly disagree, 2 moderately disagree, 3 slightly disagree, 4 neutral, 5 slightly agree, 6 moderately agree, 7 strongly agree		
I1	When I have to make a decision in my life, I tend to see all kinds of possible consequences to each choice.	Interconnectedness
I2	Social problems, environmental problems, and economic problems are all separate issues. (reverse coded)	
I3	All the Earth's systems, from the water cycle to the energy grid, are interconnected.	
C1	Ultimately, we can break all problems down into what is simply right and wrong. (reverse coded)	Controllability
C2	Rules and laws should not change a lot over time. (reverse coded)	
C3	If I make plans and control my behavior, I can accurately predict how my life will unfold. (reverse coded)	
N1	Only very large events can significantly change big systems like power grids or ecosystems. (reverse coded)	Nonlinear causality
N2	Seemingly small choices we make today can ultimately have major consequences.	
N3	It is possible for a community to organize into a new form that was not planned or designed by an authority or government.	
post survey only, open-ended response		
Q1	What sustainable engineering skills have you developed since beginning this course?	Use of sustainability skills
Q2	What are some connections you have made between sustainable engineering and your other coursework outside this class?	Use of sustainability skills
To what extent do you agree or disagree with the following statements? There are no right or wrong answers. 1 strongly disagree, 2 moderately disagree, 3 slightly disagree, 4 neutral, 5 slightly agree, 6 moderately agree, 7 strongly agree		
R1	Engineering decisions have environmental impacts.	Role of engineering
R2	Engineering decisions have social impacts.	
R3	Sustainability is a core responsibility of all engineers, regardless of discipline.	
V1	Engineering is connected to human flourishing and well-being.	Values
V2	It is important for me to do work that provides societal value.	
V3	It is important for me to do work that provides environmental value.	

To learn more about how our engineering and non-engineering students' relationship to engineering changed during *Exploring Engineering*, we created a second survey instrument. First, students self-reported their class year (ex. class of 2025 etc.), whether their major was engineering or non-engineering, and then provided their major (free response). Students who identified themselves as engineers were given the 11-item engineering identity inventory developed by [21]. Students who reported themselves as non-engineers were asked to rank their agreement with four items we created related to their intent to use engineering in their careers. Students were asked to complete this survey once in the first week of classes and once after the course's final project. In the post-survey, all students were also asked one open-ended question pertaining to their expected future use of engineering (results not presented here). The full inventory is shown in Table 3.

Table 3. Engineering identity and career intentions survey inventory

ID	Item	Construct
M1	What is your intended major at Carolina? - Engineering - Non-engineering	Demographics
M2	Specify your major (free response)	Demographics
Y	What is your intended graduation year? - 2025 - 2026 - 2027 - 2028 - 2029	Demographics
E	(Post only) How will engineering skills, tools, or mindsets you learned in this class benefit you in your future career? (free response.)	Use of engineering
To non-engineering majors To what extent do you agree or disagree with the following statements? There are no right or wrong answers. 1 strongly disagree, 2 moderately disagree, 3 slightly disagree, 4 neutral, 5 slightly agree, 6 moderately agree, 7 strongly agree		
CI1	I intend to pursue a career in engineering.	Career intention
CI2	I intend to work with engineers in my career.	Career intention
CI3	I intend to use engineering skills, tools, or mindsets in my career.	Career intention
CI4	I intend to take one or more additional engineering course(s) after this course.	Career intention
To engineering majors. To what extent do you agree or disagree with the following statements? There are no right or wrong answers. 1 strongly disagree, 2 moderately disagree, 3 slightly disagree, 4 neutral, 5 slightly agree, 6 moderately agree, 7 strongly agree N/A		
R1	My parents see me as an engineer.	Recognition
R2	My instructors see me as an engineer.	Recognition
R3	My peers see me as an engineer.	Recognition
I1	I am interested in learning more about engineering.	Interest
I2	I enjoy learning engineering.	Interest
I3	I find fulfillment in doing engineering.	Interest
C1	I am confident that I can understand engineering in class.	Competence
C2	I am confident that I can understand engineering outside of class.	Competence
C3	I can do well on exams in engineering.	Competence
C4	I understand the concepts I have studied in engineering.	Competence
C5	Others ask me for help in this subject.	Competence

Data analysis

Likert-style rating response items were translated into quantitative scores, where reverse-coded questions were scored from 7 (strongly disagree) to 1 (strongly agree) and other items were scored from 1 (strongly disagree) to 7 (strongly agree). Descriptive analyses were conducted for pre- and post-course responses and the difference between pre and post scores was calculated for each respondent. A paired t-test was used to determine if the change in responses differed significantly from zero ($\alpha = 0.05$).

Results and discussion

Enrollment and student performance

Our goal in modifying *Exploring Engineering* was to recruit students into our engineering major, and to recruit liberal arts students at our institution to study engineering and technology. While we will need to observe our course enrollments in more detail over a longer time frame to evaluate these outcomes, the first three semesters of our new engineering major suggest we have been successful attracting men and women applicants at a ratio similar to our institution's undergrad population (60%:40% women:men for all undergrads, 55%:45% women:men among our majors based on registrar data, n=31).

There were 118 students enrolled in *Exploring Engineering* in the semester the EOP framework was first integrated into the course. Among survey respondents (n=110), engineering majors and non-engineering majors earned similar grades in the course, but performance was more variable for non-engineering majors. The mean course grade was 3.7 / 4.0 for engineering majors (n=39) with a standard deviation of 0.4 points. The mean course grade was 3.5 / 4.0 for non-engineering majors with a standard deviation of 0.9 points (n=71). There was no significant difference in final grades between the two groups based on a 2-tailed heteroskedastic t-test ($p=0.09$). We did not include non-survey respondents in this analysis of grades because we did not collect major information from non-respondents. There were no significant differences in students' final grades between the semester when the EOP framework was integrated and the previous two semesters ($p>0.05$).

Systems thinking and values survey

The systems thinking, and values pre-survey was completed by 96 students, and the post-survey was completed or partially completed by 96 students. A summary of pre-survey responses can be seen in Table 4, and a summary of post-survey responses can be seen in Table 5. Reverse-coded items have been recoded in the table so that a score of 7 always represents strong agreement with a construct and a score of 1 represents strong disagreement with that construct (i.e. on a reverse-coded item, a respondent who strongly agreed with the item strongly disagrees with the construct).

Table 4. Summary of systems thinking and values pre-survey responses

Item	7*	6	5	4	3	2	1	Mean	n
I1 all possible	27	41	18	6	1	3	0	5.8	96
I2 separate issues (R)	17	25	18	13	11	8	4	4.8	96
I3 interconnected	49	26	13	6	0	2	0	6.2	96
C1 right & wrong (R)	24	29	20	10	10	1	2	5.4	96
C2 rules and laws	26	22	20	18	6	2	2	5.3	96
C3 predict (R)	11	21	21	13	17	9	4	4.5	96
N1 large events (R)	14	31	17	13	12	6	3	4.9	96
N2 seem small	22	36	26	8	3	1	0	5.7	96
N3 organize	17	30	25	19	5	0	0	5.4	96
R1 envir impacts	66	17	8	5	0	0	0	6.5	96
R2 social impacts	59	20	9	7	0	1	0	6.3	96
R3 responsibility	48	26	15	6	0	1	0	6.2	96
V1 flourishing	49	33	11	2	0	1	0	6.3	96
V2 societal value	52	23	14	6	1	0	0	6.2	96
V3 envir value	34	24	22	14	2	0	0	5.8	96

*(R): Reverse coded scores are recoded for display here, i.e. for reverse coded items a response of "strongly agree" was coded in the table as a score of 1 while for direct-coded items a selection of "strongly agree" was coded as a score of 7.

Table 5. Summary table of systems thinking and values post-survey responses

Item	7*	6	5	4	3	2	1	Mean	n
I1 all possible	27	45	16	7	0	1	0	5.9	96
I2 separate issues (R)	22	19	21	11	10	9	4	4.9	96
I3 interconnected	53	26	10	6	0	0	0	6.3	96
C1 right & wrong (R)	31	18	22	11	4	3	6	5.3	95
C2 rules and laws	26	24	21	14	4	3	2	5.4	95
C3 predict (R)	15	15	14	18	22	7	4	4.4	94
N1 large events (R)	17	32	14	15	8	6	4	5.0	96
N2 seem small	31	35	16	10	2	1	0	5.8	95
N3 organize	20	28	28	17	2	0	0	5.5	95
R1 envir impacts	64	23	1	6	0	0	0	6.5	95
R2 social impacts	59	26	4	6	0	0	0	6.5	94
R3 responsibility	52	29	7	6	1	0	0	6.3	95
V1 flourishing	54	29	4	8	0	0	0	6.4	95
V2 societal value	47	33	5	9	1	0	0	6.2	95
V3 envir value	37	36	11	11	0	0	0	6.0	95

*(R): Reverse coded scores are recoded for display here, i.e. for reverse coded items a response of "strongly agree" was coded in the table as a score of 1 while for direct-coded items a selection of "strongly agree" was coded as a score of 7.

In general, students reported agreeing with our systems thinking and values survey items both before and after the course, with most items scoring a mean 5.0 or higher. The lowest-scoring item was C3 (reverse coded), related to system controllability. Respondents were more likely to agree with the item "If I make plans and control my behavior, I can accurately predict how my life will unfold," leading to a mean score of 4.5 in the presurvey and 4.4 in the postsurvey. This suggests that while students may agree with these principles of systems thinking in the abstract, they are more hesitant to recognize the lack of controllability in their own life. Students agreed most strongly with role of engineering items (R1-3, average response of 6.4 for the 3 items), followed by the values items (V1-3, average response of 6.1). Students agreed somewhat less with systems thinking items: average response of 5.6 for interconnectedness (I1-I3), 5.3 for nonlinear causality (N1-N3), and 5.1 for controllability (C1-C3). The same pattern held in the post-survey responses. Previous research suggests that students who agree more with these systems-thinking inventory items are more likely to care about environment and sustainability [20], so our students' agreement suggests they could be motivated by the sustainability topics we incorporated.

The mean difference between students' pre- and post- responses were not significantly different from zero for any of the survey items. There was no effect of major or class year on responses. A summary of statistical testing results can be seen in Appendix A.

Engineering identity survey

The engineering identity pre-survey was completed or partially completed by 39 students while the post-survey was completed by 37 respondents. A summary of all pre-survey responses can be seen in Table 6, and a summary of post-survey responses can be seen in Table 7.

Table 6. Engineering identity pre-course survey responses

Item	7 (strongly agree)	6	5	4 (neutral)	3	2	1 (strongly disagree)	Mean	n
R1 parents	11	16	3	4	2	2	0	5.6	38
R2 instructors	4	6	12	11	3	0	1	4.8	37
R3 peers	8	9	10	10	2	0	0	5.2	39
I1 interest	28	6	2	2	0	0	0	6.6	38
I2 enjoy	21	11	3	2	1	0	0	6.3	38
I3 fulfillment	24	9	2	3	0	0	0	6.4	38
C1 understand class	8	14	10	5	1	1	0	5.5	39
C2 understand out of class	9	14	12	3	0	1	0	5.7	39
C3 exams	5	15	9	6	2	2	0	5.2	39
C4 concepts	10	10	15	2	1	1	0	5.6	39
C5 help	1	14	10	7	5	0	2	4.7	39

Table 7. Engineering identity post-course survey responses

Item	7 (strongly agree)	6	5	4 (neutral)	3	2	1 (strongly disagree)	Mean	n
R1 parents	13	16	3	3	1	1	0	5.9	37
R2 instructors	9	16	6	4	2	0	0	5.7	37
R3 peers	13	14	8	1	1	0	0	6.0	37
I1 interest	26	7	3	1	0	0	0	6.6	37
I2 enjoy	27	7	3	0	0	0	0	6.6	37
I3 fulfillment	25	8	2	2	0	0	0	6.5	37
C1 understand class	13	14	5	4	1	0	0	5.9	37
C2 understand out of class	13	14	9	1	0	0	0	6.1	37
C3 exams	11	11	11	2	2	0	0	5.7	37
C4 concepts	15	12	7	3	0	0	0	6.1	37
C5 help	9	14	8	6	0	0	0	5.7	37

As with the systems thinking inventory, a majority of engineering students reported agreeing with the engineering identity survey items in both the pre- and post-surveys. The most agreed-with items in the pre-survey were I1, I2, and I3, reflecting the participant's interest in engineering (>90% agreement for each). The least agreed-with item in the pre-survey was R2 "my instructors see my as an engineer" (59% agreed) and the second least agreed-with item was C5 "Others ask me for help in this subject" (64% agreed). In the post survey, 95-100% of respondents agreed with I1, I2 and I3, 84% of respondents agreed with R2 and 84% agreed with C5. Because this was their first engineering course for many respondents, and a first-year course for all respondents, we might expect that students' recognition and competence as engineers would increase over the semester. However this growth does not happen in all first-year engineering courses designed to promote engineering identity [22].

Based on t-test results, there were significant increases in average responses to 8 out of 11 inventory items from the pre-survey to the post-survey. Increases were seen in questions related to each of the constructs of engineering identity (recognition, interest, competence), with the smallest changes shown in the interest construct. Statistical results are summarized in Table 8. We hope that increases in students' engineering identity during *Exploring Engineering* may predict greater persistence in engineering, as was found from analysis of a national survey of graduating engineering seniors [23]. However, interventions which advance the communal and social nature of engineering can increase students' perceptions of their engineering identity (ex. competence), without changing their behaviors (ex. declaring an engineering major or applying for an engineering job) [24].

Table 8. Statistical summary of pre-post comparison for engineering identity inventory

Item	Mean difference	Standard Deviation	n	p
R1 parents	0.2	1.0	34	0.2
R2 instructors	0.8	1.3	33	0.0008*
R3 peers	0.7	1.2	35	0.003*
I1 interest	-0.1	0.8	34	0.7
I2 enjoy	0.4	0.8	34	0.01*
I3 fulfillment	0.1	0.6	34	0.3
C1 understand class	0.3	0.9	35	0.04*
C2 understand out of class	0.4	1.0	35	0.04*
C3 exams	0.5	1.0	35	0.002*
C4 concepts	0.5	0.7	35	0.0005*
C5 help	1.0	1.4	35	0.0002*

Use of engineering survey

The use of engineering pre-survey was completed by 73 students, while the post-survey was completed by 60. Respondents were divided on their intentions to work as engineers, work with engineers, use engineering skills, or take further engineering courses. Students most agreed with the assertion they would use engineering skills in the future (75% agreed) and agreed least that they would pursue an engineering career (29% agreed). There was no statistically significant change between pre- and post-course surveys for any of the four items in this survey among the 59 respondents who completed both the pre- and post-course surveys. A summary of all pre-survey responses can be seen in Table 9, a summary of post-survey responses can be seen in Table 10, and a summary of statistical testing results can be seen in Appendix A.

Table 9. Non-engineers' use of engineering pre-survey responses

Item	7 (strongly agree)	6	5	4 (neutral)	3	2	1 (strongly disagree)	Mean	n
CI1 eng career	3	6	12	17	7	6	22	3.3	73
CI2 work w/ eng	15	12	20	11	4	5	6	4.8	73
CI3 eng skills	22	18	15	9	5	1	3	5.4	73
CI4 eng course	17	6	7	15	7	8	13	4.1	73

Table 10. Non-engineers' use of engineering post-survey responses

Item	7 (strongly agree)	6	5	4 (neutral)	3	2	1 (strongly disagree)	Mean	n
CI1 eng career	5	5	10	14	7	11	8	3.7	60
CI2 work w/ eng	14	10	20	10	2	2	2	5.2	60
CI3 eng skills	18	18	13	9	0	1	1	5.6	60
CI4 eng course	13	5	8	14	4	9	7	4.2	60

Next steps

In future semesters of this course, we would like to deepen our understanding of how our students' knowledge and abilities changed during *Exploring Engineering*. We've seen from the survey results reported in this paper that students hold strongly positive *attitudes* toward systems thinking and values for their engineering work even before the course. Next, we plan to assess how well our course strengthens their abilities to *use* these two ways of thinking to address engineering problems. We plan to analyze students' work products to recognize the knowledge and skills they are using and correlate it with project outcomes.

For non-engineering students, instead of asking them about their career and course enrollment intentions, we hope to design research that helps us understand to what extent their preparedness and willingness to use engineering skills and tools changes during their participation in *Exploring Engineering*.

Conclusions

Incorporating learning outcomes from The Engineering for One Planet framework into our general education first-year engineering course enabled us to develop systems thinking and values thinking throughlines for the course. Both before and after the course, students strongly agreed with our systems thinking attitudes inventory and strongly valued engineering contributions to society. Between the beginning and end of the semester, engineering students grew in some measures of their engineering identity while non-engineering students did not change in their reported intentions to pursue engineering. While students likely had many experiences outside *Exploring Engineering* which impacted their engineering identities and career intentions, most engineering students take this course in their first year when they are not concurrently enrolled in any other engineering courses. Moving forward, we will seek to deepen our understanding of how systems thinking skills develop in our students, and what contributes to their success using systems thinking to solve engineering problems.

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Appendix

Table 11. Statistical summary of pre-post comparison for systems thinking, role of engineering, and values inventory

Item	Mean	Standard deviation	n	p
I1 all possible	0.1	1.2	96	0.4
I2 separate issues	0.1	1.4	96	0.7
I3 interconnected	0.2	1.1	95	0.1
C1 right and wrong	-0.1	1.2	95	0.6
C2 rules and laws	0.1	1.2	94	0.5
C3 predict	-0.1	1.5	95	0.6
N1 large events	0.1	1.6	96	0.6
N2 seem small	0.19	0.9	95	0.055
N3 organize	0.1	1.1	95	0.4
R1 envir impacts	0.0	0.8	94	0.8
R2 social impacts	0.1	1.0	95	0.3
R3 responsibility	0.1	1.0	95	0.2
V1 flourishing	0.0	0.8	95	0.7
V2 societal value	0.0	0.9	95	0.7
V3 envir value	0.26	1.0	95	0.01*

Table 12. Statistical summary of pre-post comparison for non-engineers' use of engineering

Question	Mean	Standard Deviation	n	p
CI1 eng career	0.3	1.4	59	0.07
CI2 work w/ eng	0.3	1.6	59	0.1
CI3 eng skills	0.2	1.4	59	0.4
CI4 eng course	0.1	1.8	59	0.7