Impacts of Engineering Engagement Activities for First-Year Students

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Engineering Engagement for first year students: The effect of required participation in engineering engagement activities

Abstract: Serving the demands for future engineering professionals in our society requires increasing retention of students in year one. This study is focused on students enrolled in Innovation in Design, which is a semester-long introduction to engineering course for freshmen students at a large research university in the northwest. The course is an interactive, hands-on experimental introduction to several engineering discipline projects and employs a flipped classroom approach to explain fundamental engineering concepts before students apply and test those concepts in the classroom experiments. This structure exposes students in year one to engineering applications, with an additional piece of the course designed to further engage students in the engineering school and research activities. The Engineering Engagement assignment, which is the focus of this study, is posed to broaden student exposure to engineering outside of the classroom. Our approach consists of two types of engagement, where students choose between attending a research seminar or a club meeting. Assessment of the effect of engagement activities on motivation was performed with the Science Motivation Questionnaire II, adapted to engineering courses. Test results were analyzed using three engineering engagement activities: research seminar, club meeting, and senior presentations as independent variables and the five motivation constructs from the SMQ-II as dependent variables. None of the constructs showed statistical significance.

Introduction

The need to increase the numbers of engineering graduates has often been discussed[1], as indicated by the President's Council on Jobs and Competitiveness' commitment to increasing graduation rates in engineering disciplines[2]. It has long been recognized that the introductory engineering courses within the first year of the engineering curriculum play a critical role in student attitudes towards engineering as a suitable profession[3]. Active learning classroom techniques, particularly those that focus on engaging freshman students in carefully chosen design projects[4], are connected to increased student mastery of the course subject material[5]. First year engineering design course implementations are used in many universities with the goals of exposing freshman engineering students to different aspects of professional engineering work and of engaging students in controlled design projects[6]. It is also broadly acknowledged that the success of engineering students increases with modest participation in extracurricular activities[7], because participation in extracurricular activities increases student engagement[8].

Some universities have overhauled the entire first-year engineering curriculum to integrate engineering design in every course taken by freshman engineering students with promising results[9, 10], yet these articles also note the significant time requirement for faculty members in preparing the sweeping curriculum changes[11]. Researchers at other universities have investigated the effects of augmenting or modifying the traditional first-year engineering design course with extracurricular activities to engage students in the engineering profession. Merritt et. al. reported on an initiative in which mentorship and research seminars were combined into a semester-long research seminar class in which first-year students were assigned to groups of eight based on student individual preferences; the authors examined just one seminar group in-depth as a case study[12]. Chesler et.al, recognizing the multiple stakeholders involved in the freshman engineering design course, constructed a virtual internship for freshman students to encourage students to begin thinking of themselves as engineering professionals, yet this inquiry also provided only a single bioengineering focused option[4]. Introducing two pre-selected case studies into a traditional freshman engineering course, Kilgore et al. measured the ability of freshman students to include context and application in the problem-scoping phase of a design project[13]. These researchers suggest that context-oriented approaches in the curriculum increase retention of female students because female students generated an average of 2.37 more context-specific design requirements than the male students; however, students were not allowed to individually select case studies based on personal interest. Within a single department at another university, Fox et.al. found 90% of first semester students valued the experience from a project linking a freshman biosystems engineering design course to the senior biosystems engineering design course, with freshman students acting as subcontractors for the seniors[14]. These modifications to the traditional freshman introduction to engineering design course require less preparation time and effort for faculty and instructors to implement. Yet the comparative effect of the different types of engineering engagement activities on student motivation to continue in the engineering degree track, implemented side-by-side in the same course with different students selecting different activities, has not been studied in freshman students.

There is a need for interventions which mitigate professor effort to affect freshman motivation to continue in engineering curriculum. In this study we utilized the Science Motivation Questionnaire II (SMQ-II) to quantify the connection between freshman engineer engagement in activities outside the classroom and motivation to continue in engineering[15]. We follow the approach of Lackey et.al.in tracking how a single non-technical assignment can predict academic success[16], but our study is distinguished from earlier work in that the emphasis in this study is on student motivation. In this study we compare the effects on motivation of three different engagement activities that are modifications to an existing freshman engineering course.

Methods

At a large land-grant university in the Northwest, the course Engr 120: Innovation in Design, is a two-credit, one-semester course taught in both the fall and spring. The course is required for majors in bio-, civil, environmental, and mechanical engineering and is open to students from chemical, computer, and electrical engineering. Engr 120 surveys discipline-specific projects before cumulating in an interdisciplinary project at the end of the semester. The condensed single semester course time is countered by encouraging students to engage with individual engineering disciplines outside of the classroom. Students are allowed to self-select into the available engineering engagement activities. Students are required to participate in at least one 'Engineering Engagement' extracurricular activity during the semester and to write a one page report on their experience at the end of the semester.

Students may choose to attend a presentation for the senior design projects for an engineering department, attend a faculty research seminar presentation, or participate in an engineering student club meeting. The number participating in the study totaled 60 students, with 28 attending student clubs, 21 attending a research seminar, and 11 choosing senior design project presentations as their engagement experience. The senior design presentations were either poster presentations in electrical and civil engineering or oral presentations in mechanical engineering; Engr 120 attendees were to ask at least one question of the senior design team presenters. Faculty presentations for the Civil and Environmental, or Mechanical Engineering departments were part of the graduate seminar series, and the freshman students were not required to ask a question of the presenter. The ~~freshman were~~freshmen were given the option to attend these graduate level research seminars, even though it was unlikely the freshman students would fully understand the research topic. The engineering club meetings were organized by the various student clubs within the *** College of Engineering and Architecture, involving presentations, work days, community building, and mentorship activities.

Motivation Construct	Question	Question statements
Intrinsic Motivation	1	The engineering I learn is relevant to my life.
	3	Learning engineering is interesting.
	12	Learning engineering makes my life more meaningful.
	17	I am curious about discoveries in engineering.
	19	I enjoy learning engineering.
Self-efficacy	9	I am confident I will do well on engineering tests.
	14	I am confident I will do well on engineering labs and projects.
	15	I believe I can master engineering knowledge and skills.
	18	I believe I can earn a grade of an “A” in engineering.
	21	I am sure I can understand engineering.
Self-determination	5	I put enough effort into learning engineering.
	6	I use strategies to learn engineering well.
	11	I spend a lot of time learning engineering.
	16	I prepare well for engineering tests and labs.
	22	I study hard to learn engineering.
Career Motivation	7	Learning engineering will help me get a good job.
	10	Knowing engineering will give me a career advantage.
	13	Understanding engineering will benefit me in my career.
	23	My career will involve engineering.
	25	I will use engineering problem-solving skills in my career.
Grade Motivation	2	I like to do better than other students on engineering tests.
	4	Getting a good engineering grade is important to me.
	8	It is important that I get an “A” in engineering.
	20	I think about the grade I will get in engineering.
	24	Scoring high on engineering tests and labs matters to me.

Table 1: Question statements from the SMQ-II, question number and motivation construct each statement relates to. These question answers were averaged and used for the MANCOVA analysis.

To assess the Engineering Engagement assignment impact on student motivation, The Science Motivation Questionnaire II (SMQ-II), in the Appendix, was employed and modified to represent engineering rather than science vocabulary. Developed by Glynn, et al. at the University of Georgia, the SMQ-II has been validated by both science and non-science majors and focuses on five motivation components: intrinsic motivation, self-determination, self-efficacy, career motivation and grade motivation[15, 17]. Table 1 represents each question statement and the motivation construct related to that question. The survey is a five-point Likert scale with the selections for each value as follows: five – always, four – often, three – sometimes, two – rarely, and one – never. The instrument uses five constructs with five questions in each, for a total of twenty-five questions.

We administered the student survey via the Engr 120 course website, and students were awarded extra credit for participation. The data were averaged for each of the motivation components, mentioned above, and run using a MANCOVA test in SPSS. This test was chosen to observe the relationship between the multiple engagement activities and the five dependent variables, the motivation constructs at the end of the assessment. It tests for significance between the grouped means for the motivation constructs. In the test, the motivation constructs were used as dependent variables and the type of engagement as the independent variable. The MANCOVA generated descriptive statistics including mean, standard deviation and the significance for each motivation construct. Additionally, the mean and standard deviation were calculated for each question in the survey.

Results and Discussion

The data collected from the pre-/post SMQ-II assessment are tabulated and presented in Table 2 which describes the engagement activities and aligns them with the motivation constructs. It also shows MANCOVA results with significance values, while Figure 1 shows means and standard deviations from the scores on the posttests.

The respective post means for each group from the MANCOVA results shed more light on the differences between the engineering engagement activities effect on student responses. The overall mean for career motivation and grade motivation constructs were 4.56 ± 0.58 and 4.41 ± 0.55, respectively. The other three motivation constructs had means with self-determination at 3.98 ± 0.56, self-efficacy at 4.10 ± 0.61 and intrinsic motivation of 4.08 ± 0.72. While there are differences in the respective means, the MANCOVA calculated significance for each construct does not indicate statistical significance. However, it is important to note some differences between the types of experiences the students had in each engagement activity.

Those students who attended a research seminar most likely experienced very technical, high-level discussion that had components the students had never encountered in a lab or classroom setting. The level of discussion was probably too technical and detailed for the students to follow along. Conversely, the senior design presentations have some design teams that will make a clear compelling case with sufficient technical detail for their design while presenting the information at a level that less experienced attendees, such as the freshmen Engr. 120 students, can understand and appreciate. Other teams may not have spent as much time on their projects, leaving out technical details with presentations that are clearly of a lower standard. In short, some senior design teams will give an excellent presentation while other senior design teams will give poor presentations. The clear distinction between quality and poor senior design presentations may alert the freshman students that quality work, as indicated by higher grades, is important for an engineer. Finally, club meetings may offer a social network and connection to other more senior students in the engineering program. They can encourage students to engage with the development of interpersonal skills and work ethic. These experiences may also broaden student’s perspective, with the realization that more than high grades contribute towards hiring decisions.

Motivation Construct	Engagement	Mean	Standard Deviation	Significance
Intrinsic Motivation	Senior Design	4.02	0.77	0.94
	Seminar	4.07	0.61	
	Club Meeting	4.11	0.70	
	Total	4.08	0.72	
Self-efficacy	Senior Design	4.07	0.76	0.78
	Seminar	4.05	0.57	
	Club Meeting	4.16	0.59	
	Total	4.10	0.61	
Self-determination	Senior Design	4.04	0.55	0.56
	Seminar	4.05	0.61	
	Club Meeting	3.90	0.54	
	Total	3.98	0.56	
Career Motivation	Senior Design	4.65	0.46	0.70
	Seminar	4.59	0.29	
	Club Meeting	4.49	0.77	
	Total	4.56	0.58	
Grade Motivation	Senior Design	4.51	0.38	0.59
	Seminar	4.46	0.49	
	Club Meeting	4.34	0.64	
	Total	4.41	0.55	

Table 2: Mean post scores and MANOVA significance values for the five motivation constructs on the SMQ-II questionnaire.

In addition to the quantitative data that was collected, at the end of the post SMQ-II assessment students were asked three additional short answer questions: 1) the name of the Engineering Engagement activity they attended; 2) whether or not they intended to continue participating in the activity in the spring semester; and 3) what were the best and most challenging aspects of the activity. A single student who completed the SMQ-II survey did not complete the essay question responses. The first essay question was used in the statistical analysis for differentiation between the Engineering Engagement Activity groups, and the latter two essay questions were analyzed for qualitative data to accompany the MANCOVA results.

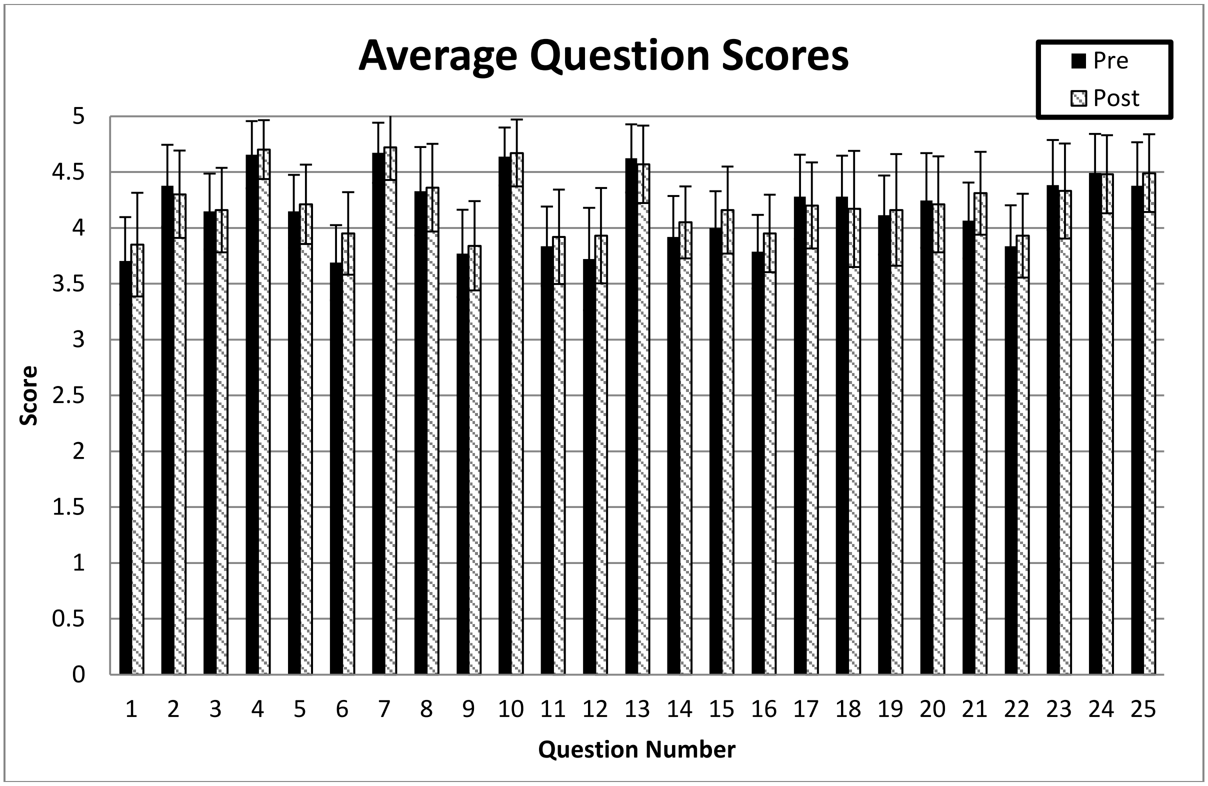

Figure 1: Mean scores and standard deviations of pre- and post-questions on the SMQ-II .

The responses to the essay question about continued participation in the engineering engagement activities were varied, and very much linked to the type of engagement a student elected. As shown in Figure 2, 57% of the students who elected to attend a research seminar to complete the Engineering Engagement assignment did not intend to continue participating in research seminars. In contrast, those students who elected to participate in a student club meeting demonstrated an overwhelming intention, 67%, to continue attending the same or another engineering college student club in the spring semester.

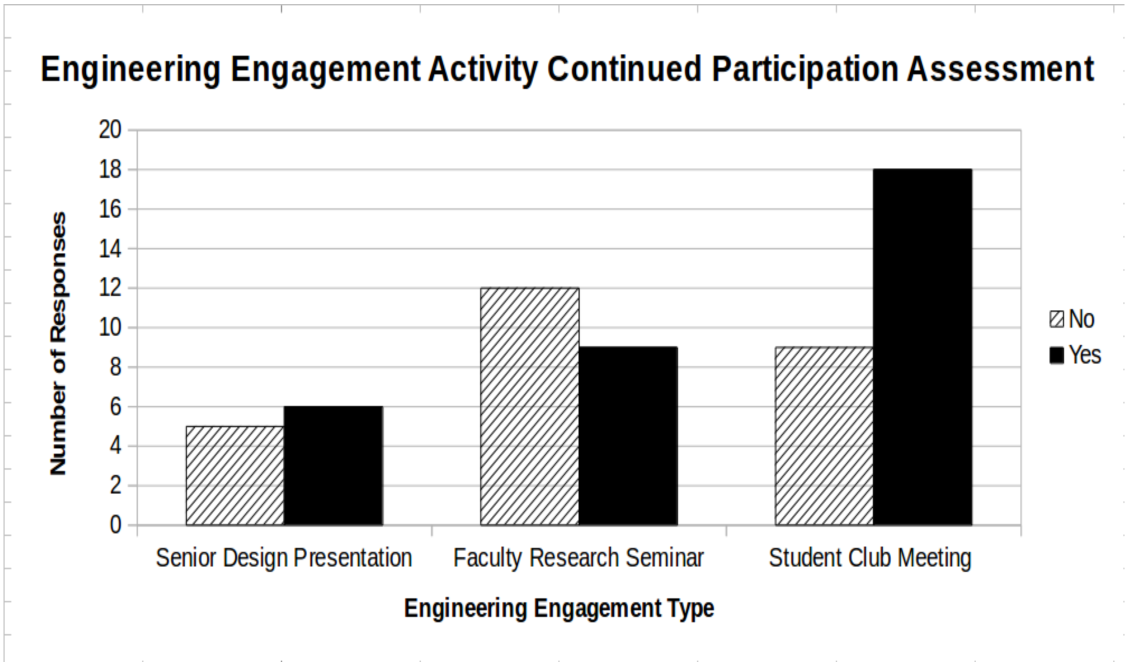

Figure 2: Intention to continue participating in selected Engineering Engagement Activity during the following semester.

The responses to the best and most challenging aspects question were analyzed using an online word cloud generator [18] to identify the eight most often used words from all of the student responses in each of the three Engineering Engagement activities. After controlling for common words, such as engineering and words from the essay question prompt, the remaining most common words for each Engineering Engagement category were compiled and are shown in Table 2.

Table 2: Eight most common words used in student responses about the best and most challenging aspects of their selected Engineering Engagement activity with the percent of word occurrence per student indicated in parentheses.

Senior Design Presentation	**Faculty Research Seminar**	**Student Club Meeting**
projects (91%)	knowledge (43%)	club (85%)
presentations (45%)	see (43%)	time (44%)
students (45%)	understand (43%)	people (37%)
people (36%)	presentation (38%)	meeting37%)
interesting (36%)	learning (38%)	work (33%)
made (36%)	talking (33%)	interested (33%)
posters (36%)	lecture (33%)	one (30%)
understand (36%)	made (33%)	group (26%)

Students who elected to attend the senior design presentations and the student club meetings used more words which indicated a sense of community, such as people, interesting/ed and group, than did the students who elected to attend the research seminar. In contrast, students who elected to attend the research seminar described the event in passive terms, focusing on the difficulty in understanding the seminar topic. One student who attended a research seminar wrote:

"The best part about my engineering engagement was learning a little bit of a new field. Now I have a little bit of a background in this new field and I've expanded my knowledge. The most challenging part was following everything the speaker was talking about because some of it went over my head. But the next time I learn about this topic I'll have some background in it and it'll be easier to follow."

The selection of words used by students to describe the student club meetings are more active words, particularly work, indicating that these Engr 120 students were more actively involved in the student club events as compared to the students participating in the senior design and research seminar presentations. Another student response demonstrates the active nature of the student club meetings:

"The best part of steel bridge team was seeing how the seniors and juniors apply their knowledge with the various programs in order to create the bridge. I am excited to finally have enough knowledge to do the same as them in the following years. I am excited to begin construction of the bridge next semester with the team. I am excited to see how we place in the competition in spring."

A third student remarked on the mentorship which occurred during the club meetings:

"The best part of the meeting was during and after we ate, when we just talked at the table about different classes we were taking, what they were like, and what to be careful about. It was a great time to meet all of the mentors working with the program, because we talked to several different people before we ended up making a decision about who we wanted as our mentor. The time was about matching personalities as well as interests within the mechanical engineering field".

The active participation of students in the student club meetings, along with the mentorship provided by upperclassmen engineering students, could cultivate freshman engineering student enjoyment of engineering.

The lack of a significant difference among the three different Engineering Engagement activity options demonstrates that all three activities have a nearly equal effect on student motivation; in most cases the motivation of students increased at the end of the semester after the completion of the activity. Thus, while none of the currently implemented Engineering Engagement activities show a significant ability over the other two activities categories to improve student motivation, all three activity groups contribute to a statistically equal incremental and desirable increase in student motivation.

The qualitative analysis indicates that of the three options for engineering engagement, the research seminar had the most effect on decreasing student intrinsic motivation. These seminars are designed for graduate students, and the technical details were often confusing and daunting for the freshmen Engr 120 students. The short answer responses that 57% of students did not wish to participate in a research seminar again could indicate that students were discouraged by the research seminar.

Students who elected to participate in the student club meetings demonstrated an increase in learning about engineering compared to the other students. This increased enjoyment of engineering is reflected in the overwhelming number, 67%, of freshman students who do intend to continue attending student club meetings in the future. Accordingly, future Engineering Engagement activity development ought to focus on two goals: ensuring that the presented material is suited for a freshman audience, and creating a learning community focused on active participation of students.

Conclusions

This study involved 60 freshman engineering students enrolled in Engr 120 at a large land grant research university in the Northwest. Participants self-elected into one of three engineering engagement activities: listen to a research seminar, attend a senior design project presentation, or participate in a club meeting. The effect of these three activities on student motivation was assessed using the SMQ-II with twenty-five questions, divided into five motivation constructs: intrinsic motivation, self-efficacy, self-determination, career motivation, and grade motivation. MANCOVA using SPSS was run with the engagement type as an independent variable and the motivation constructs with dependent variables. Qualitative analysis with the most commonly used words were collated from three short answer question responses. None of the motivation constructs had statistical significance. The most-used words from each short answer question were more active for the senior design project and club meeting and more passive from the research seminar. Taking the qualitative results in combination with the minimal significance among the groups from the SMQ-II MANCOVA analysis, future engineering engagement activities should have technical material curated for freshman engineering students and have an active engagement component that fosters a community among the students.

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Appendix

Engineering Motivation Questionnaire II (SMQ-II)

In order to better understand what you think and how you feel about your engineering courses, please respond to each of the following statements from the perspective of "when I am in an engineering course…"

1. The engineering I learn is relevant to my life.
2. I like to do better than other students on engineering tests.
3. Learning engineering is interesting.
4. Getting a good engineering grade is important to me.
5. I put enough effort into learning engineering.
6. I use strategies to learn engineering well.
7. Learning engineering will help me get a good job.
8. It is important that I get an "A" in engineering.
9. I am confident I will do well on engineering tests.
10. Knowing engineering will give me a career advantage.
11. I spend a lot of time learning engineering.
12. Learning engineering makes my life more meaningful.
13. Understanding engineering will benefit me in my career.
14. I am confident I will do well on engineering labs and projects.
15. I believe I can master engineering knowledge and skills.
16. I prepare well for engineering tests and labs.
17. I am curious about discoveries in engineering.
18. I believe I can earn a grade of an "A" in engineering.
19. I enjoy learning engineering.
20. I think about the grade I will get in engineering.
21. I am sure I can understand engineering.
22. I study hard to learn engineering.
23. My career will involve engineering.
24. Scoring high on engineering tests and labs matters to me.
25. I will use engineering problem-solving skills in my career.