Exploring Students' Class Perceptions in the Development of a First-Year Engineering Design Course

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This complete evidence-based practice paper describes the examination of students' perceptions in the development of a First-Year Engineering Design course. Developing effective courses requires inputs from various stakeholders including students. In addition, students' perceptions of courses and their associated activities have been related to students' motivation to pursue and persist in an engineering major. Recognizing the importance of these views, this evidence-based practice paper investigates first year-students' perceptions of an Engineering Design class that is being developed emphasizing the Human-Centered design process. We used the MUSIC Model of Academic Motivation to explore the ways students perceived the pilot version of the class. Qualitative and quantitative data were collected by means of an online survey. We expect to identify aspects of the class that are both meeting the overall course goals and supporting students' academic motivation as well as aspects of the class that might need improvement according to students' observations. The results of this analysis will help in the ongoing development of the class and ultimately increase the quality of the new course to better support students' academic motivation and success.

Introduction

Helping first year engineering students develop foundational engineering skills while at the same time getting them excited about being an engineer is a challenge that many instructors, course developers, and other stakeholders within first year engineering programs encounter every day. When trying to reach this goal, it is necessary to understand the extent to which students intend to engage in the classroom environment, and how pedagogical and curricular approaches affect students' academic motivation [1]. Introductory engineering courses are one common element in many engineering colleges nationwide. There is growing recognition in research that experiences related with courses taken in the first year, and the level of success in these courses, are directly related to students' achievement and retention, more than many other factors [2,3].

This evidence-based practice paper describes the examination of students' perceptions of a first-year multidisciplinary engineering design course. This course was created to improve the experience of engineering students by inspiring them to be makers and use their engineering skills to design solutions that help solve societal problems. In this way, we expect to help students make connections between engineering and society early enough in the curriculum [4].

Methodology

The goal of this paper is to highlight and share the results of the development of an engineering design course and its impact on students' academic motivation. Although these results can not be generalized, the characteristics of the engineering design course experience could be transferred to other similar institutions with first year introductory courses.

The Course

The course is a 2 credit hour course structured in a flipped-classroom format. Students watch a number of short (~15 minute) lecture videos at home (for a total of ~1 hour a week of online video content) in preparation for a single 2-3 hour session per week of active learning with the professor and peer mentors in a makerspace classroom. Online lecture videos each week are structured to build the skills that will be practiced live in-class. This flipped classroom format is utilized for optimizing makerspace classroom time for active-learning and to allow the flexibility of students to watch and re-watch the online videos as many times as needed to be comfortable with the content prior to hands-on activities [5].

The eight larger goals for the course are:

1. Understand and practice the human-centered engineering design process for a societal based project
2. Learn techniques to solve open-ended engineering challenges
3. Promote a culture of making by introducing solid modeling, programming, sensors, data acquisition, 3D printing, and other maker tools
4. Build teamwork and cooperative learning skills through participation in multidisciplinary teams and active engineering project management
5. Build professional skills in background research and written, pictorial, and oral communication methods
6. Raise awareness of ethics and contemporary issues in engineering design related to a global society
7. Introduce engineering students to the various engineering majors and their roles within society
8. Inform students of opportunities for experiential learning related to their majors throughout the college of engineering and university community

The course content includes the emphasis on The Human-Centered Design Process which is practiced both individually and in teams. Students are then exposed to various maker-skills to help them create their human-centered prototypes. By the middle of the semester, the larger societal-based team open-ended project is revealed, and student teams are given six weeks to research, design, build, program, and document their functional prototypes. In the project student teams are required to both design and build a physical prototype that involves physical, mechanical, electrical, and programmed components. While documenting is done throughout the design & build process, there are two weeks at the end of the semester for finalizing a formal engineering design report on their created prototype and presenting their functional physical design [5]. For a more detailed description of the course please see [5].

Theoretical Framework and Research Question:

Academic motivation is defined as “a process that is inferred from actions and verbalizations, whereby goal-directed physical or mental activity is instigated and sustained [6]”. Understanding students’ academic motivation is crucial for enhancing students’ learning and students’ choices in engineering [7]. While there are many theories of motivation, the MUSIC model of academic

motivation is especially useful to study students' perceptions of the course because each of the components of the model reveals aspects about the design of courses based on motivation theories [6]. These perceptions are important because they are research-backed steps that can help to make small but significant changes that can improve students' academic motivation, which in turn improves students learning. Previous studies have suggested that student perceptions of academic experiences are critical factors to understand their developmental outcomes [8,9].

Thus, the research question for this paper is: *What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?*

In this study, students' perceptions are defined as the extent to which students recognize each of the components of the MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) model of academic motivation. Specifically, the extent to which students differentiate that:

- they have control of their learning (eMpowerment);
- the coursework is useful to their goals (Usefulness);
- they can succeed at the coursework (Success);
- the instructional methods and coursework are interesting (Interest); and
- others in the course (such as the instructor and their peers) care about learning (Caring) [6].

Thus, students' perceptions were measured by using the MUSIC model inventory included in a survey implemented at the beginning and at the end of the semester. In this survey, students were asked about each of the MUSIC model components (for a more detailed description of the MUSIC Model Inventory please visit http://www.themusicmodel.com/inventory website). Student demographics questions based on gender, major, year of study, and ethnicity background were also included in the survey.

Results:

Participants Demographics

The participants in this study are mostly freshman (46/48) engineering students enrolled in the pilot version of an elective introductory design course at a large, public university in the United States. Participant demographics by gender and ethnic background are displayed in figures 1 and 2 respectively. Figure 3 displays students declared engineering majors or undeclared when students are still deciding which engineering major to pursue. Figures 4, 5, and 6 display student prior build, solid modeling, and programming experience, data collected throughout the survey.

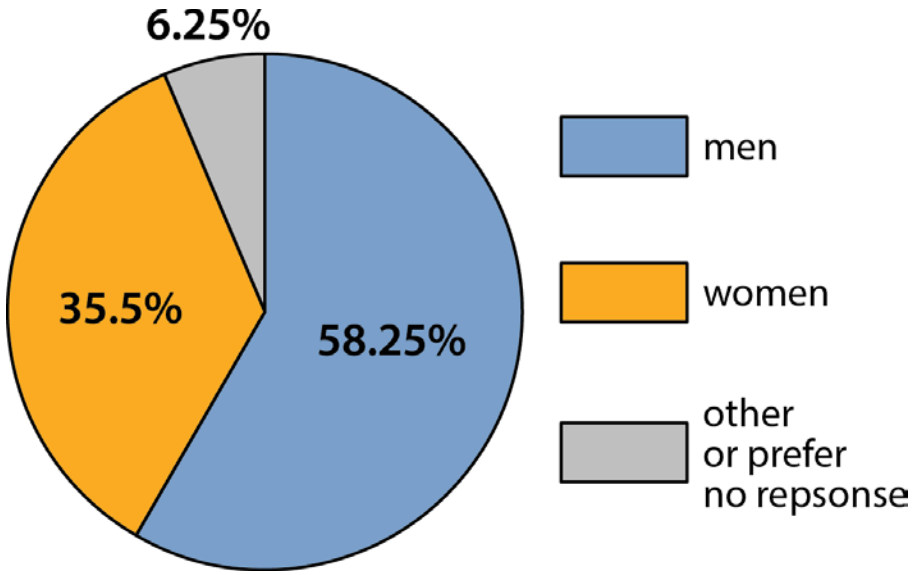

Figure 1. Participant Demographics by gender.

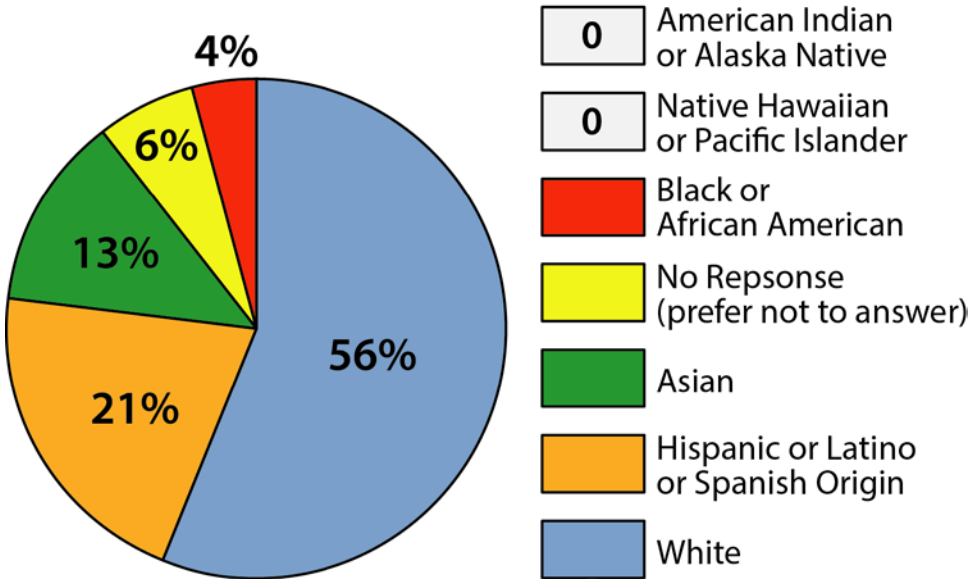

Figure 2. Participant Demographics by ethnic background.

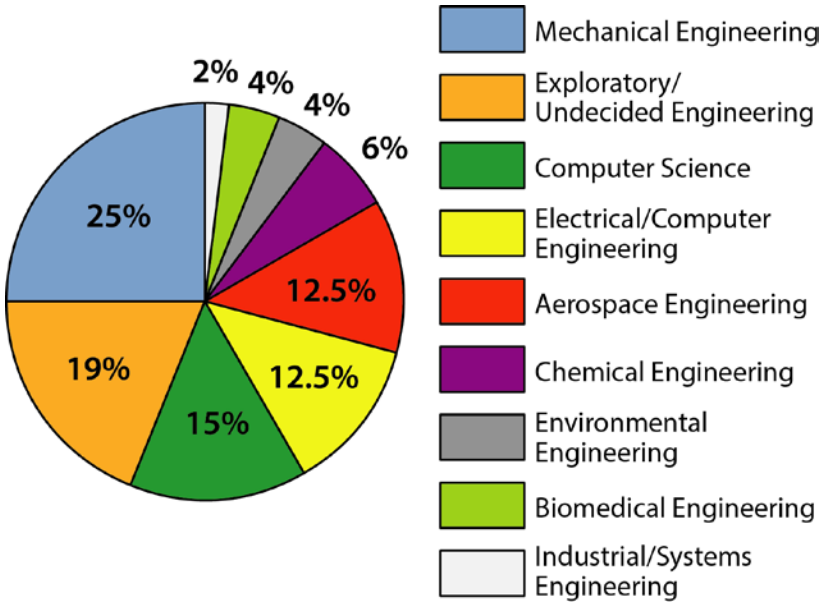

Figure 3. Participant Demographics based on declared engineering majors.

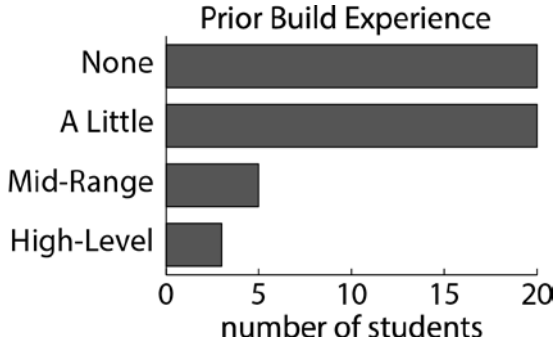

Figure 4. Students build experience prior the course

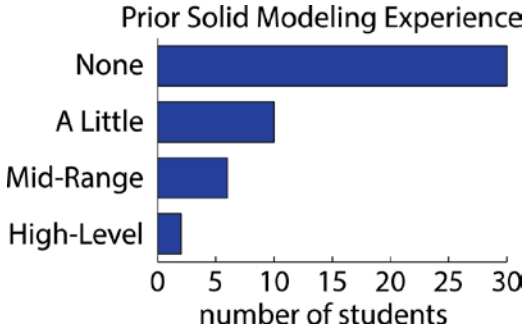

Figure 5. Students solid modeling experience prior the course

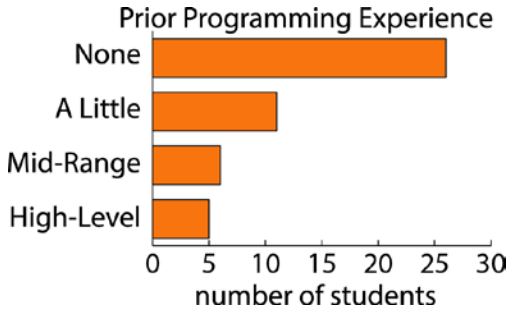

Figure 6. Students programming experience prior the course

Students' perceptions

This section presents the initial analysis from student responses to the surveys. First, the quantitative part consisted of 26 questions from the MUSIC model inventory. All these quantitative items were rated using a 6-point Likert-type scale ranging from strongly disagree to strongly agree. Students were asked to answer the questions based on their experience in the course, including assignments, activities, videos,etc. A sample item from each component is as follows in Table 1:

Table 1

Sample Items from the Components of the MUSIC Model

Sample Item	*MUSIC model component*
"I had the opportunity to decide for myself how to meet the course goals."	eMpowerment
"The coursework was beneficial to me."	Usefulness
"I was capable of getting a high grade in the course."	Success
"I enjoyed completing the coursework."	Interest
"The instructor was available to answer my questions about the coursework."	Caring

Students were invited to complete the MUSIC model inventory that includes 26 six-point Likert scale questions. In addition, 5 open-ended questions corresponding to each of the component of the MUSIC Model (Empowerment, Usefulness, Success, Interest, and Caring) were included in the survey. The following tables present the results of the survey for each of these components. For each construct, the average of the items was calculated representing the means scores at the

beginning and at the end of the semester for all students participating in the study. Next, initial codes are included along with representative quotations from student responses.

Empowerment

What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?	
Construct	**Empowerment**
Mean Beginning of the semester	4.91
Mean End of the semester	4.93
N	48
Question: Which aspects of this course give you control over this course?	
Shared perceptions about the course	**Example quote**
Creative process	*"We are free to solve the human-centered design problems given to us in our own way by designing something based on our own creativity and prior knowledge."*
Flexibility	*"The design project set a goal, but how that goal was to be accomplished and the various choices and their justifications were up to oneself and one's team. I think the guidance given, such as the benchmark assignments along the way, was beneficial and did not hinder flexibility."*
Open-endedness	*"The problems that we had to answer we very open ended. There were few rules that would others be constraints to creativity, so I felt free to use the knowledge I had."*
Choice of pacing	*"The aspects of this course that give me control over it are the singular deadlines for assignments. Because there is only one deadline for us to worry about, we can plan out the work we need to do at the pace that works best for us."*

Usefulness

What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?	
Construct	**Usefulness**
Mean Beginning of the Semester	5.3
Mean End of the Semester	5.36
N	48
Question: What could be changed in this course to make it more useful to you?	
Shared perceptions about the course	**Example quote**
Project choices	*"Instead of only building the self-watering planter, possibly having a couple of options in what we would like to build for our project. Or even better, have free reign in what we would like to build for our project."*
	"Almost nothing, perhaps one change could be choices between final project designs"
Programming instruction	*"There could be more instruction on coding"*
	"More emphasis on programming."

Success

What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?	
Construct	**Success**
Mean Beginning of the Semester	5.13
Mean End of the Semester	5.12
N	48
Question: What made you feel as though you cannot be successful in this course?	
Shared perceptions about the course	**Example quote**
Not having prior knowledge	*"Sometimes I feel as though I cant be successful in this course because I have no knowledge of circuits and the various components that allow engineers to create products. However, I feel comfortable learning in this environment."*
	"That I had no skills in coding, modeling, or anything really compared to everyone else"
Nothing	*"Nothing in particular makes me feel less confident about my success in this class"*
	"Nothing really, I felt I could be successful throughout the course."

Interest

What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?	
Construct	**Interest**
Mean Beginning of the Semester	4.99
Mean End of the Semester	5.05
N	48
Question: What did you find interesting about this course?	
Shared perceptions about the course	**Example quote**
Design process	*"I thought learning about human-centered design and having the freedom to create my own designs was very interesting."*
Hands-on experience	*"It's a class early on in the engineering track that gives you some hands-on and design experience."*
Technological skills	*"The most interesting part of this course is learning to use technological skills and then having the opportunity to apply them and create a unique product (self-watering planter)"*

Caring

What are some of engineering students' perceptions based on the MUSIC Model of Academic Motivation of a multidisciplinary engineering design course?	
Construct	**Caring**
Mean Beginning of the Semester	5.57
Mean End of the Semester	5.58
N	48
Question: What does the instructor did to provide you with the impression that she cares about whether you learn the course content and do well in the course?	
Shared perceptions about the course	**Example quote**
Encouraging	*"She goes out of her way to make sure that everyone has a firm enough grasp of the material, and is extremely encouraging. She is constantly available to provide assistance, and will go out her way to make sure students are successful."*
	"She is very open to questions and genuinely cares about both the coursework and our understanding of the purpose of the course. She does not discourage our designs but still suggests improvements to help us become better."
Questions	*"She always came around to check on our progress and regularly asked us if we needed help or had any questions"*
	"She was always open to answering questions and offering help."

Discussion

The goal of this evidence-based practice paper was to explore students' perceptions of an newly developed introductory engineering design course. Data analysis of the quantitative scores indicated that all the components were slightly higher at the end of the semester except by the Success component that was slightly lower at the end of the semester as indicated by the mean scores for each of these constructs. The qualitative data allowed exploring some of the reasons behind the quantitative scores.

Empowerment: Results revealed that this component was slightly higher by the end of the semester. According to Jones [6], Empowerment refers when students perceive that they have some choices over the way they learn. Some of the initial codes emerged from the qualitative data indicated that students felt autonomous by having control over the "creative process", "flexibility", "open-endedness", and "choice of pacing". These codes are not surprising given the focus on open-ended engineering challenges and projects throughout the course. Empowerment refers to the need to feel autonomous. When empowerment is used appropriately by providing students with choices, assigning problems with multiple solutions, and allowing student to express their own ideas can be an effective academic motivator [6].

Usefulness: Results revealed that this component was slightly higher by the end of the semester. Usefulness refers to students' perceptions that the course content, assignments, or activities are useful to their goals in life [6]. For this construct, we used the question "*What could be changed in this course to make it more useful to you?*" instead of "*What aspects of the course are useful to you*". The reason for this is that as course developers, we wanted to make sure to get students'

suggestions for the class. The most prevalent initial codes for this construct included “final project choices” and “more programming instruction”. For students, giving a variety of choices for the final project could have made the course more useful to them. It is probable that by having more choices for the final project, students might have more potential ways that they can benefit from, especially considering that students pursue different engineering disciplines. Students also said that having more programming instruction could have made the course more useful. This makes sense since students prior level of experience with programming ranged from *none* to *little* experience. Probably providing more guidance in the programming aspect of the class may give students more confidence in this area and learn the content better for their short and long-term goals.

Success: The mean score for this component was slightly lower by the end of the semester. This component refers to students’ beliefs that he or she can succeed if they put forth adequate effort [6]. Similar to the wording for the question in the Usefulness component, for Success we asked: “*What made you feel as though you cannot be successful in this course?*” because we were interested in any aspect that could be hindering students’ beliefs about their success in the class. The two most prevalent codes for this component was “Not having prior knowledge” and “Nothing”. Again, these findings are not surprising, according to the additional demographic data collected in the survey, students build, solid modeling, and programming prior experience was very limited. Matching the difficult levels of class activities and assignment with student abilities is important in order to keep students more motivated [6]. The ability of students to accurately estimate their level of success in the open-ended challenges while they were still learning/practicing the necessary skills might be influenced by the prior experience level on these skills. Other students repeatedly reported that “Nothing” made them feel they cannot be successful; these students might have succeeded in similar tasks in the past. One student mentioned, “Instructions were clear and he was interested”. Another student discussed that “appropriate time and resources were always available for assignments” while another student pointed that “Nothing really made me feel this way because if I had any problems regarding coursework or my own general knowledge, I could very easily approach my instructor or one of my peer mentors for guidance.” All of these are examples of strategies to trigger Succes in academic settings [6].

Interest: The Interest component was higher at the end of the semester. Interest refers to students’ perception of enjoyment of a given academic task [6]. In other words, students are interested in an academic task when they like the activity. The initial codes for this component were “Design Process”, “Hands-on experience”, and “Technological skills”. Strategies that are suggested to trigger academic interest include those experiences that attract students’ curiosity and attention. The opportunity of working with the Arduino boards, 3D printers, and modeling software tools allows piquing students’ curiosity. Many students described that learning about the Human-centered design and having the freedom to create their own designs was very interesting. This is important considering that this is a course developed to be early in the engineering curriculum, thus these type of activities may help fostering longer-term student

interests in engineering as suggested in the engineering education literature [9].
Caring: The Caring component was slightly higher at the end of the semester. Caring is associated to *relatedness*, described by [10] as "the desire to feel connected to others - to love and care, and to be loved and cared for" (p. 231). The prevalent initial codes for this component were "Encouraging" and "Questions". Fostering a class culture where students feel challenged and at the same time encouraged to participate is a practice suggested to better support students' perception of caring. Consequently, when students experience relatedness, they feel more comfortable asking and answering questions, benefiting engagement in learning activities [6].

Conclusions

The goal of this paper was to explore students' perceptions of a new introductory engineering design course. The authors believe in the adoption and development of teaching strategies based on existing research. The results of the analysis in this study allowed highlight the potential use of instructional practices and strategies based on educational research as well as get students' suggestions for the overall improvement of the course. Given the importance of students' course perceptions in their motivation to pursue an engineering degree, continuous and effective assessment of engineering courses should be made to ensure that students are given the opportunity to have a better perception of their learning environment. The MUSIC model presents an inventory that could be implemented in the assessment of any course. The results of similar studies can help interested stakeholders include students' input for the overall assessment of the different curricular approaches in the courses.

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