Effect of Evolving Design Requirements on Students' Motivation

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Work in progress: Effect of evolving design requirements on students motivation

Abstract

In 2008, Gannon University was awarded a National Science Foundation S-STEM grant, known as SEECS (Scholars of Excellence in Engineering and Computer Science) which provided scholarship funding for academically talented students having financial need. Since then, the grant has been funded twice more; the current award period started in 2017 and will run until 2021. As a requirement for the SEECS program, all students must participate in a community-based design project, undertaken for a non-profit entity in the local region. This project is nominally a two-year effort, though some projects have taken longer to complete. Recently, a project has experienced several significant setbacks: 1) the original project sponsor decommitted at the end of the first year due to funding concerns; 2) the project location changed four times due to uncertain sponsor requirement and city regulations; 3) the design itself has required substantial alteration several times due to unexpected circumstances (largely due to sponsor issues.) After two and a half years, the project remains only about 50% complete, still requiring additional system level design, installation and testing. This team of SEECS students has been coping with each "sharp turn" of the project as well as may be expected. They have produced design sketches, prototypes, and conference presentations. Yet signs of confusion, frustration, and low motivation level have been observed among students and have been evidenced through student satisfaction surveys, which are administered to all SEECS students each semester.

This work-in progress paper details the evolution of student perceptions of the validity of the project, compares that evolution to historic data obtained from previous design groups, and speculates about the cause/effect relationship between externally-imposed design changes and student perceptions. In particular, the effect of design changes on student enthusiasm and sense of purpose is to be examined. Preliminary conclusions and trends will be drawn from the study. The periodic evaluation, adjustment and intervention of advising will be suggested to guide students to fully benefit from such real-life project experience.

Keywords: S-STEM, motivation, scholarships, community service project, student success

Section I: Introduction

The "Scholars of Excellence in Engineering and Computer Sciences" (SEECS) program was established in 2008 at Gannon University, funded by the National Science Foundation (NSF) Scholarships in Sciences, Technology, Engineering and Mathematics (S-STEM) program [1]. Since then, the grant has been funded twice more; the current award period started in 2017 and will run until 2021. The goals of the program, the structure, and its assessment have been published in several conferences [2] - [4]. One of the highlights of the program is that all students must participate in a community-based design project, undertaken for a non-profit entity in the local region. This project is nominally a two-year effort, though some projects have taken longer to complete. Some projects experienced multiple significant design modifications, installation location change, and even a totally new design after one year into the project, mainly

due to stakeholder requirement changes, funding availability, and sponsor changes. The team of SEECS students has been coping with each "sharp turn" of the project as well as may be expected. Yet signs of confusion, frustration, and low motivation level have been observed among students and have been evidenced through student satisfaction surveys.

This work-in progress paper details the evolution of student perceptions of the validity of recent and ongoing projects, and speculates about the cause/effect relationship between externally-imposed design changes and student perceptions. In particular, the effect of design changes on student enthusiasm, motivation, perception of value, and group dynamics is to be examined. Preliminary conclusions and trends will be drawn from the study. The periodic evaluation, adjustment and intervention of advising will be suggested to guide students to fully benefit from such real-life project experience.

Section II: Motivation

As design efforts proceed, perhaps as a result of the long design timeline for SEECS projects, it has become common for changes of project scope to occur. Some changes have been minor, of the sort that one would expect from any reasonably-sized project. Others have been more problematic, arising from changes in client wishes or capabilities that have necessitated wholesale alterations and even complete discard of nearly-finished design results. The focus of this paper is evaluation of student motivation as a result of large-scale changes.

Design techniques exist that are based upon the obviation of uncertainty due to fuzzy requirements. Within the field of software engineering, as a prime example, it is somewhat common to have ill-defined requirements at the beginning stage of a project. One way to combat this is use of "Agile Engineering," which utilizes a suite of techniques that have been adopted to allow simultaneous evolution of design and design requirements [5]. The hoped-for result is a rapid design process accomplished through extreme flexibility. Oversimplifying, the method is based largely upon prototype development and testing, incorporating extensive teamwork. While this approach seems to be well-regarded within the software community, it has not yet been widely adapted to mechanical design, perhaps due to its reliance upon prototypes, with their attendant costs and possible safety issues.

The fundamental issue with design change, from the perspective of engineering education, is not the requirement changes themselves. The issue that is to be looked at here is "how do these design changes affect students' attitudes and behaviors?" In answer to that question, there seems to be little to be found in the engineering literature. However, help may be found within the Human Resources community. In some sense, a change in design requirement might be likened to a change of policy within a business. There is much to be learned from HR as to how policy or procedure changes affect the morale of employees [6], [7].

Following guidance primarily to be found in the literature of Human Resources, Organizational Management, and design practice, this work-in-progress seeks to understand motivational changes within students and identify likely strategies to deal with those changes resulting from significant change in project requirements.

Section III: Projects Descriptions and Change of Scope

Project 1 – Green Power Generation and Distribution Center Design

This project is currently ongoing, and while it is not the project which originally sparked the analysis of this paper, it is a project that may be instructive. The project is to create a power-generation station from a piece of equipment located in the campus Recreation and Wellness Center. While creation of a bicycle-generator (for example) is not necessarily novel, this project is novel in its implementation. The current iteration envisions a network of bicycles all producing power independently for use at a centralized distribution point. The bicycles cannot be directly networked due to restrictions on how the room is used, so there is a "portability" issue as well as a "distribution" issue to tackle.

Student satisfaction with this project seems to be on a declining trajectory. These authors believe this decline in satisfaction is attributable to both change of scope, lack of clear direction, and overall poor fit (in the eyes of some students) to academic major.

Beginning in fall 2017, students were tasked with identifying a particular piece of equipment to use as a basis for the device – treadmill, rowing machine, spinning bike, or pin-select weight machine. Initial enthusiasm from the customer was high, but soon fell off due to concerns about violation of warranty for existing equipment. This of course caused a great deal of angst among students, and an immediate sense of futility. Compounding this was a fluctuation on the end-user's end as to how the generated power is to be used. In short, lack of clear goals by the end user have made this project more difficult for students to embrace than might be desired. Nevertheless, the needs of the seminar program include "design," so the instructors have seen to it that the students press on.

As of this writing, progress in student engagement with the project seems to have been made by purchase of an inexpensive stationary bike for students to design to, along with procurement of several key parts from other, no-longer-needed projects. Having a physical object in hand (so to speak) has allowed students to better envision devices that will work and which can be incorporated without intrusive mounting, thus producing a design that is less likely to void warranty, when implemented on the client's equipment. Figure 5 demonstrates the student's enthusiasm for the project; student comments indicate that purchase of the surrogate bike had a measurable, positive effect. The lesson seems to be "hands on is best, even if hands are not on the 'correct' equipment."

Student engagement seems also improved by an executive decision made by the students' instructors: since there has been no very clear message about how the power will be used, students are free to select their own use – with the caveat of a centralized use point for all power created. This caveat is a work-around so that other uses of the power can be implemented later.

Timeline of this project is roughly as follows:

- Fall 2017, Freshman first semester: The task this semester was to define the project. Students were expected to choose the target exercise equipment and the target use for the power generated.

- Spring 2018, Freshman second semester: Owing to inability to connect with the end user and conflicting signals from that user, students were unable to make progress in the most basic of tasks – those meant to be identified in the first semester. Also, at this point, some students began to openly complain that the project was not major-specific to them and thus not worth the effort, from their perspective. This may have been the feeling at the outset of the project, but lack of progress may have made this feeling become explicit. But students did settle on a basic concept – using a stationary bike, removable battery packs, and centralized display kiosk to use the power generated.

- Fall 2018, Sophomore first semester: Students were again thrown into chaos, as an older bike promised by the end user as a prototype development tool was declared to be unavailable. Students were tasked with making decisions about batteries, determining needed components, identifying likely means of connection to the existing bikes, etc. But without a bike to work on – a lack that students attributed to end-user apathy and/or confusion – instructors found students to be quite difficult to motivate. This was rectified by purchase of a "random" stationary bike (that is, one that had no specific similarity to the final bike to be used, except for possession of a spinning flywheel) and provision of basic equipment known by the instructors to be necessary for design implementation. Students at the end of the semester were finally "hands on," and beginning to show some signs of enthusiasm.

Figure 1. Phases of the Green Power Generation. Moving from left to right: images of fitness equipment at the Recreation and Wellness Center evaluated for this project; spinning bicycles were selected towards the end of the freshmen year; prototype work during sophomore year.

Project 2 - Renewable Energy Power Station

The project for the current Junior cohort group is to set up a renewable energy station on the roof of the physical plant building to harvest wind and solar energy into electricity and utilize the electricity for lighting and to charge the batteries of the power tools – or other use as the client finds convenient. The location of the proposed system has been changed multiple times, as shown in Figure 2.

Figure 2. Four phases of the renewable energy power station. Phase I Bayview Park: Freshmen year; Phase II Bus stops on campus: the summer after freshmen year; Phase III Knight club roof: Sophomore year; Phase IV Physical plant building roof: the summer after Sophomore year till current.

The scope of the project has also been changed along with the evolving of the location. For phase I, it was to "design a replicable, aesthetically pleasing attraction that uses renewable energy to provide a charging station for a minimum of two mobile devices, lighting, and the capability of connecting to the grid". When the students were informed that they had to give up the location of the Bayview Park due to uncertainty of the master plan of that region, they dived into design for bus stops right away with enthusiasm. After selecting the bus stop right outside the Knight Club (an on-campus student coffee shop), they realized that the entire roof of the Knight Club might be available, so the system size was scaled bigger, for the newly-identified location. The focus shifted from "aesthetically pleasing attraction…" to "harvest renewable energy to reduce the utility bill for the Knight Club". Students spent time and effort to search for suitable system for the roof size and researched regulations for the site. Unfortunately, due to the weakness of the roof structure and uncertain future plan of the Knight Club building, a sharp turn has been made to install the selected system to the roof of the physical plant building. In summary, the location has been changed four times within the 2 years of the project duration, only once by student choice.

The survey results shown in Figure 4 clearly indicate the negative impact of multiple project scope and location changes to all four aspects of the surveys. Their enthusiasm and motivation both have the highest value at the beginning of the freshmen year, and then fall steadily along with every change, reaching their lowest value at current. Their perception of value holds resiliently till the end of the freshmen year, but falls sharply at the end of the sophomore year. Their group dynamic started with a relative low value and kept falling to an even lower value at current.

Project 3: Pennsylvania Soldiers' and Sailors' Home Artifact Display Unit

The project undertaken by the current senior class is one that underwent only minimal evolution in the requirements. The device to be created was a rather simple one, a case for protection and display of historical artifacts, namely military uniforms. The uniforms represent all branches of the US armed forces, and mostly date from World War II. The case is designed to protect these irreplaceable artifacts from damage due to heat, light, humidity and vandalism while also providing full visibility and an interactive display capability. The case was to be mobile, self-

contained (aside from electrical connection to a standard wall outlet) and attractive. This project was undertaken in service to the Pennsylvania Soldiers' and Sailors' Home of Erie, PA.

At the outset, the customer desires were rather vague, but once settled upon, there was little change in customer expectations, aside from an eventual realization that the direct client might have overstated his ability to get funding, so that some fundraising was needed by the students. This project is one for which the students show good and increasing satisfaction over the time the project was proceeding, with a slight drop-off afterwards (see Figure 3). This slight drop-off is interesting, but not likely unusual, as the novelty of the experience of design wears off as the design activity recedes into the past.

Section IV: Methods

A study was conducted by surveying all the students currently active in the SEECS program, and through the analysis of previous projects provided by the authors of the paper, all of whom are co-PIs in the NSF S-STEM Award. The survey was developed based on the goals of the study, with several rounds of review and revision to ensure that the questions would be interpreted as intended. Paper copies of the survey were distributed to 25 students during class time. Survey data was analyzed using standard methods while written comments were analyzed using open coding in order to identify common themes.

Section V: Results and Discussion

Figure 3 shows the temporal evolution of enthusiasm, motivation, perception of value and group dynamics for the current senior class starting from the beginning of their first year until the end of the fall semester of their senior year. The scope of this project (Project 3 in the previous section) did not change significantly and only minimal change in customer expectations occurred during the time the project was proceeding. As it can be seen in Figure 3, almost every parameter shows increasing behavior until the completion of the project. Then, a slight drop-off can be observed which can be due to lack of challenge and engagement associated with the end of the project.

Additionally, the survey provided open-ended questions where students could identify the factors that affected the changes in their perceptions. The seniors were very satisfied with their experience and one stated that "*…it got more exciting and we could see the project coming together*." This comment was shared by all 80% of the seniors. This is clearly reflected in the increases in enthusiasm.

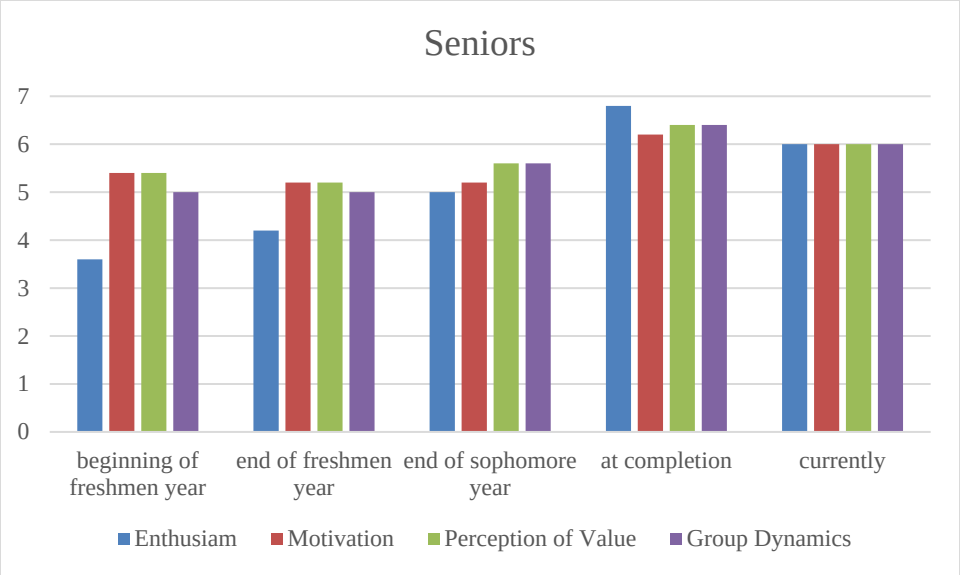

Figure 3: The results of the survey for the senior class.

The results of the survey for the current junior class are depicted in Figure 4. This project (Project 2 in the previous section) has had significant changes in its scope along with the change of the location of the project. Almost every single parameter shows decreasing behavior during the time that the project was proceeding. The students started the project with a high level of enthusiasm, motivation and perception of value. However, all these parameters were negatively affected by the significant change in the location and consequently scope of the project. The group dynamics seems to be the parameter that was influenced the least by these changes, however, it has decreased as time proceeded as well.

The answers to the open-ended questions provide insights to the results in Figure 4. 71% of the juniors mentioned the changes of scope of the project as the reason to the decrease in the enthusiasm. 57% of the juniors stated that the project started with a high value to the community but the current usage will be limited; this changed has negatively affected the perception of the value.

Figure 5 shows the evolution of enthusiasm, motivation, perception of value and group dynamics for the current sophomore class starting from the beginning of their first year until the end of the fall semester of their sophomore year. The scope of this project (Project 1 in the previous section) changed significantly. Similar to the junior class, it can be seen that the change in the scope of the project has affected the students negatively. This is evident by the decrease observed in all the parameters after the beginning of the project, shown in Figure 5.

The sophomores were also asked open-ended questions related to the causes of the changes in their perceptions. Students stated that the lack of interest and direction from the stakeholder has contributed negatively to the perception of the value of the project.

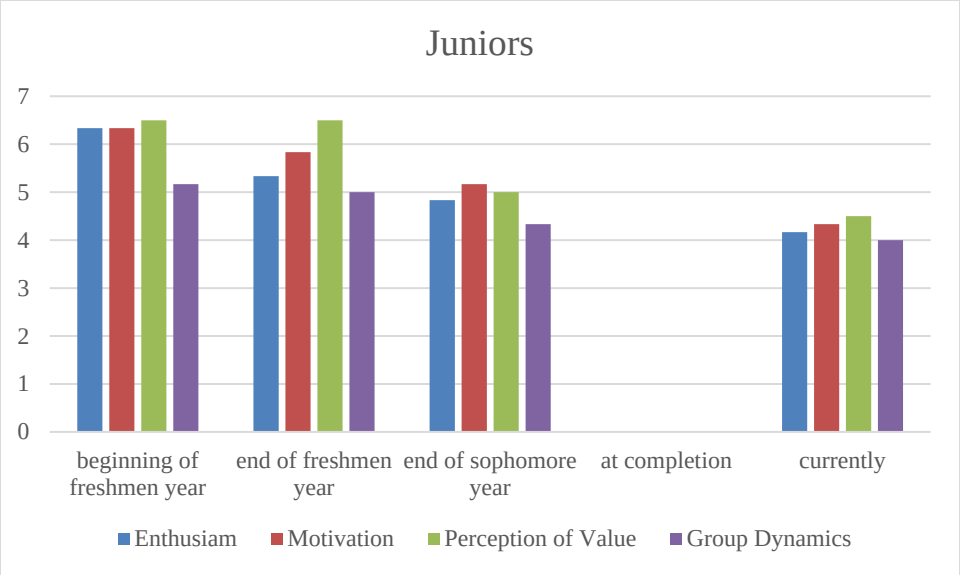

Figure 4: The results of the survey for the junior class.

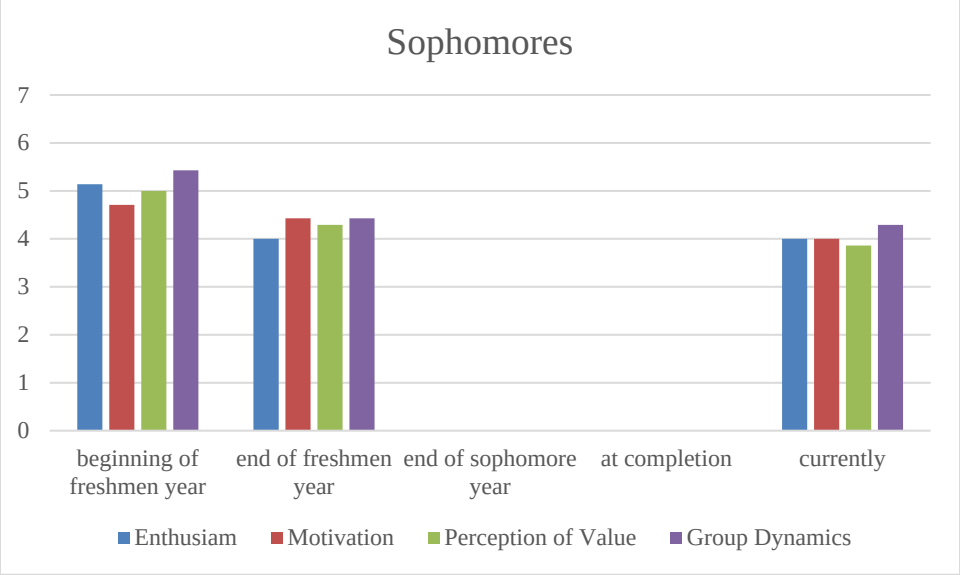

Figure 5: The results of the survey for the sophomore class.

The results of the survey for the current freshmen class are depicted in Figure 6. This project has been running for one semester. All factors have increased, especially enthusiasm, throughout the semester as the project has been defined in more detail.

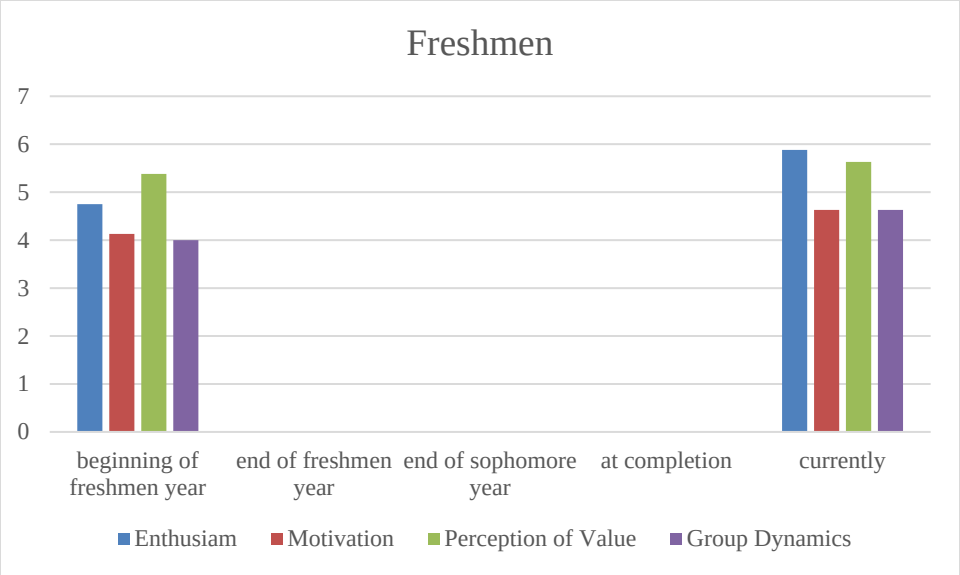

Figure 6: The results of the survey for the freshmen class.

Section VI: Conclusion

The preliminary results of this study provide evidence that large-scale changes in the scope of a design project may affect student motivation, enthusiasm, group dynamics, and the perception of value. The first two parameters can have a great impact in a student's persistence in their major. A longitudinal study will be continued to obtain data to support this hypothesis. Additionally, the goal would be to identify ways to mitigate these effects to ensure a better student experience.

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