AC 2011-2151: DIFFERENCES BETWEEN STUDENT AND FACULTY EXPECTATIONS FOR A ROBOTICS CAPSTONE DESIGN PROJECT

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Differences between Student and Faculty Expectations for a Robotics Capstone Design Project

Abstract

The typical U.S. engineering curriculum begins with three years of structured coursework followed by a final year of technical electives and the choice of a relevant capstone design project. In mechanical engineering this project is designed to integrate the concepts from these courses towards the production of a working mechanical system. Unaccustomed to making connections between this course material and hands on design, students often have difficulty seeing how this type of book knowledge is relevant towards the solution of an authentic design problem. This issue can best be expressed through the differences in expectations among the students and their faculty advisor, and when compared, highlight some of the discrepancies between the two viewpoints. To investigate this issue, a series of interviews was conducted between a set of capstone design students and their faculty advisor on a mechanical engineering team preparing an entry for an autonomous surface vehicle (ASV) competition. The interview protocol contained items addressing prerequisite knowledge and experiences, project expectations, and where this knowledge was, or should have been, acquired. Results indicate that there are differences between students with only college experience, those with some industry experience, and the faculty advisor with several years of experience with the specific design task. These differences illustrate real world understanding of the classical design process and show how it can be utilized to achieve greater integration in an authentic design context.

Introduction

The typical U.S. engineering curriculum is structured as three years of preparatory coursework culminating in a fourth year of technical electives and a capstone design project related to a student's interests. This design project experience is intended to unify the concepts presented in previous coursework and demonstrate the application of engineering science to an authentic design task that simulates industry practice. While this concept may seem straightforward, the expectations for projects of this magnitude often differ between students and their faculty advisors[1]. While students with industry experience tend to be more open to the iterative and creative processes recommended by their project advisor, students who have only completed coursework with limited "hands-on" experience tend to view engineering design as the development of a single correct solution for a given design problem statement[2].

The changes necessary to move students from these novice conceptions of design to more experienced designers require the ability to understand the engineering design process as a tool rather than an inflexible constraint towards the development of a single product. By comparing the perceptions of students and faculty through a series of interviews and observations, this study takes initial steps towards the advancement of novice designers to more experienced ones, in line with the expert faculty advisor's expectations.

The design process that the faculty advisor referenced in the group's design meetings was in many cases a modification to what students were exposed to in lecture, ultimately resulting in frustration from the less experienced students and wasted time for those who had seen it before. The purpose of this work is to begin the discussion and offer suggestions on how to better bridge the gap between novice student designers and those which represent more industry-ready ones. Specific to this goal was the determination of relevant experiences and knowledge helpful for a valued team member, and whether students felt that this knowledge was an expected prerequisite or something that was to be acquired through the capstone experience itself.

Methods

Context

The autonomous surface vehicle (ASV) competition is an annual competition run by the Association for Unmanned Vehicle Systems International. The association coordinates and runs six competitions with its main objective being "to focus on the future of this rapidly growing industry and to develop programs to attract and equip students for a career in robotics and unmanned systems community"[4]. Of the six competitions the ASV competition, the "RoboBoat", represents a design challenge for students to develop an autonomous boat that must navigate an obstacle course while completing four separate challenges testing the capabilities of the boats' programming, sensing, and actuation within a scored timed trial.

Participants

The participants for this study came from a mid-Atlantic engineering focused institution and were all in the final year of their undergraduate curriculum. All students came exclusively from a mechanical engineering background and were enrolled in this capstone design project as a course requirement for graduation within their major. These students were given the option to enroll in one of forty-one projects, with this particular project having an enrollment limit of ten students. Of the ten student team members, eight agreed to be interviewed. Of the student participants, there were seven males and one female with experience ranging from coursework only, to several years in industry. Amongst these students were three active members of the United States Navy, and two additional graduate research assistants in charge of the "technical success" of the final prototype. The faculty advisor (male) has served as an assistant professor and advisor for similar competitions over the past 12 years. All data for the project was collected during the first semester of a two-semester course sequence. These meetings occurred twice a week, once with the audience of the faculty advisor and once without. Each meeting lasted for roughly an hour and fifteen minutes.

Data Collection and Analysis

This study is the first of a three phase interview protocol consistent with qualitative research aimed at understanding the lived experiences[5] of a team of capstone design students. The interview protocol consisted of ten questions addressing the past experiences and present expectations for the coming design project and ranged from 15-40 minutes in duration and took place on campus during the first six weeks of the semester. The faculty advisor was interviewed in his office. All participants signed an IRB-approved informed consent form and were provided with the transcription of their interview to check for accuracy.

In addition to the interviews, field notes were collected and weekly team meetings audio recorded with particular note being taken of the differences in language used by the team members versus the faculty advisor.

The interview responses and field notes were inductively coded through a two phase system[6]. While the initial codes were developed based on the emerging themes and common statements, these were later consolidated into four core categories that constitute the results section of this work. The nature of this integration is highlighted by the joint titles and synthesized results below.

Results

Overall the interview responses showed more agreement between students with greater amounts of industry experience with those of the faculty advisor than from students with less experience. While students with less experience remained concerned about prerequisite knowledge, and tended to overstate the importance of each step in the design process, more experienced students remained confident that the capstone experience itself was what was important and where most of the specific knowledge would be attained; the differences between these two viewpoints is expressed in the following sections.

Pre-requisite Knowledge vs. Learning through Design

When asked "What skills and experiences do you believe have prepared you to contribute to this project?" and "Do you believe that these are necessary prerequisites or could these be learned throughout this project?" student responses varied based on their amount of real-world industry experience.

"All three years we have designed all this stuff but we never actually made anything until now". With so much emphasis on the placement of the capstone design project at the end of the curriculum, the design project acts as the logical conclusion to these previous years of work. When asked about specific prerequisite knowledge required to be a valued member of this team, undergraduate participants' responses ranged based on their levels of industry experience.

With one student convinced "You can probably learn it [relevant content knowledge] all with the team" another stated the necessary prerequisite knowledge was limited to "learning terminology" and having the confidence to "ask the right question". One of the prevalent feelings expressed was that most of the learning in their coursework was independent of senior design and that without linking these two areas students felt more skeptical about the role of their "book knowledge" in their career plans.

Of particular note was the issue of estimation and assumption. One student felt like she was "skipping steps that they did last year" with reference to the construction of an early prototype before the design process was complete. Another student was displeased with the pace of the project stating "I really feel that these teams are reinventing the wheel every single year" and should not spend as much time working on design steps that teams from the past had already completed several times over. In fairness, these design teams have remained fairly consistent over the years with advisors often advising the same teams for the same competitions. These differences in perception of the experience are also a testament to how students' growth as engineers allows them to view the techniques they learned in school as a more of a tool and not a rigid constraint.

While participants with only limited practical experience cited specific courses, more experienced participants, with who had either industry experience through co-ops or internships, believed that specific knowledge was not relevant, but valued knowledge of "what the design process entails" as expressed the feeling that "most of [the necessary knowledge] will be learned while working on the project". This is an important point because if students are not made aware of the connections to their previous coursework then they may not see the relevance of the capstone experience as the logical conclusion of their undergraduate experience. In addition to this, students may feel that either they did not learn useful information during their courses, which may affect their attitudes about engineering and ultimately their motivation during their capstone experience.

Of the skills most commonly referenced were the need to work in a team, be able to communicate questions and issues with others, and where to seek help when obstacles arise. As one student stated, "you could have a degree in history" as long as you can problem solve and understand the design process. The advisor agreed, noting that students need only "general knowledge" related to the project, and that the "design process is their focus". This is important as specific knowledge related to robotics was not mentioned, being ultimately the responsibility of the graduate students for the success of the project.

Access and Interdisciplinarity

When asked if students from other majors could valuably contribute to this project, and at what point in the curriculum, students mentioned "electrical engineering", "ocean/aerospace engineering", and "computer science" while questions regarding when and if such a project should be made available earlier than senior year, participants were overwhelmingly in favor (7/8 students and the faculty advisor) of opening the project up to not only students earlier in the curriculum, but also from other disciplines. The only dissenter of the group stated that this should be considered on a "case by case basis" dependent on the project.

When asked for specifics the main consensus was that a junior level of engineering science understanding should be sufficient. This level of knowledge would have been contingent upon successful completion of courses such as “system dynamics”, “fluid mechanics”, and a relevant “programming course”. Aligned with this experience students also mentioned the benefits of a greater comfort with the “language of engineering”. This language barrier was also referenced by the faculty advisor when he said his main concern was that his students “to be able to go to the expert and ask the right question. Not that they need to have the answer already, but they need to have the confidence with the language”.

While the participants were generally in support of this idea, the reasons by which they came to this conclusion varied. With one student stating that he “definitely [thought] that [he] could have done it last year”, and another that beginning on a project only as a senior “doesn’t give you a whole lot of experience” there was more of a concern with the fact that “I don't see us using any skills that we learned through our education”. Even the faculty advisor admitted that “when possible I try to enroll students earlier on”.

In addition to opening up the project to other undergraduates, the incorporation of students from different disciplines was discussed. Of the available majors at the given institution students most cited their desire for the inclusion of electrical engineering, computer science, and ocean/aerospace engineers as the most likely candidates. One student made the point that in “the real world it’s not like we’re going to be working with just mechanical engineers”, and also that to “learn something one should be familiar with other [disciplinary perspectives]”.

In addition to their views on this the faculty advisor mentioned that he has been “trying to enroll electrical engineering students in [the] project but since [we] don’t have a required capstone course in that major, they are not registering.” While being outside the focus of this work, this does bring about another issue in that curricular change at this level must be embraced at all levels within the college and across disciplines.

Role Definition

With thirteen total members working on the project, ten undergraduate students, two graduate students, and the faculty advisor, the formal role of each member was determined by the level of technical skill possessed by the individual as determined by the faculty advisor. With so much detail going into a project of this magnitude, he decided that the undergraduate students’ role was mostly “to design the boat using the design process” with the research assistants in charge of the “technical details” and the faculty advisor acting as the “project manager”. While the advisor was referred to as a “coach”, “project manager”, or “boss” students did not consider themselves players, employees, or engineers; instead, students still mostly saw themselves as students in a class. And as students in a class, their primary concern was with “the quickest way we can get a good grade…that's the bottom line”. When referencing the level of commitment of himself versus those of his team this student expressed his frustration by stating “Do it, send it out in two hours, no one is going to care because no one wants to spend extra time." This classroom atmosphere was expressed in a student's final thought, "I've recently stepped back and thought about this and we are not learning how to design a boat, senior capstone is to review your design process in a project setting".

The main problem with this mentality is that there is a clear disconnect between not only team members, but more importantly, with their advisor. While some students view this experience as "just another class", others take to it as a challenge and a place to gain experience toward their careers. These viewpoints were not disputed by the faculty advisor whom was realistic in his assertion that "students have other classes" and with students receiving assignments and a grade for their membership on the team, it is understandable why students would perceive the capstone experience as "just another class". In regards to the usefulness of role definition he stated that his undergraduate students should develop "the ability to work in a team", "explain reasoning behind decisions", and understand who to approach and "how to ask the right question".

Discussion

While the focus of this work was on the differences between student and faculty expectations and initial feelings, many of the specifics (i.e. content knowledge and an interest in robotics) related to this being an ASV team turned out to be irrelevant compared to the larger issues of communication and what capstone design means to the individual. Expressed often through the series of interviews was the belief of less experienced students that capstone design is just another class and should be treated as such. This came in contrast to the few students who had experience in the Navy and engineering industry who saw capstone design as something more; these students showed to be more active in the group meetings, and often times showed greater involvement in the team decisions.

Prerequisite knowledge was also an important issue. Since this team was exclusive to mechanical engineering and robotics, it was originally thought by this researcher that involvement required certain technical knowledge. This did not turn out to be the case as students and faculty felt strongly and consistently that success required only general engineering knowledge and the "confidence to ask the right question of the right person". While student interview responses mentioned teamwork and lifelong learning, other relevant ABET criteria were not referenced implying that students did not feel they applied or did not understand within the context of this experience.

In addition to prerequisite knowledge was the issue of communication. Students agreed that in order to communicate proficiently for a project of this complexity that two years of coursework, including completion of courses such as "system dynamics", "fluid mechanics", and a relevant "programming course" would allow for them to not only understand the terminology and basic science of the project, but also where to go when roadblocks occurred. From the faculty advisor's point of view these were important with the addition of the ability to estimate and make accurate assumptions so that the interplay of design parameters could be observed, evaluated, and progress made on a steady basis.

This study continues through the second semester to investigate the phase of the project directly following completion of the initial prototype. It is during this time that students must begin to solve the individual design sub-challenges and represents the first divergence from standard procedures that have been completed several times throughout the curriculum. It is also possible that during this time students will have greater flexibility in the choice of their solutions to smaller scale problems which may allow for enhanced creativity compared to the earlier and more standardized phases of the project.

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