TRANSLATING AN HONORS INTRODUCTORY ENGINEERING COURSE FOR A NON-HONORS ELECTRICAL AND COMPUTER ENGINEERING (ECE) POPULATION: INITIAL DATA

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Abstract

Background

Throughout the past five years at The University of Houston, a first-year program has been developed and refined for a small group (approximately 50 students per semester) of honors engineering students. Through that program, the level of technical achievement in the first-year honors students increased significantly, as did the motivation levels of the students.

Purpose

The purpose of this paper is to present the preliminary results of a pilot introductory PBL course in ECE that scales up an existing honors engineering first-year program that had already demonstrated success. Issues encountered and best practices learned from adapting a multidisciplinary honors engineering PBL course to a single discipline non-honors PBL course will be presented and discussed. The research question guiding this study is therefore, "How do motivation and self-efficacy levels differ between honors and non-honors engineering students in a first-semester project-based course?"

Methods

A paper survey was administered to students in both the honors version of the Introduction to Engineering course and the non-honors version. The honors students were a multidisciplinary group of 52 students enrolled in the university's Honors Engineering Program. The ECE group consisted of 101 students who were enrolled in the ECE program or who intended to apply for admission to the ECE program. Self-reported data from both groups were collected. Descriptive statistics and effect sizes for measures of motivation and self-efficacy were analyzed and reported.

Significance

Although there is quite a bit of literature concerning the benefits of implementing evidence-based instructional methods such as PBL in the classroom, there is considerably less literature addressing how PBL impacts different populations within engineering. This research informs those curriculum developers who are either in the early stages of creating new PBL courses in engineering or who are thinking of scaling up current PBL programs to a different population.

Introduction

There is ample evidence that project-based learning (PBL) and learning communities help students to understand the relevance of their studies, improve their attitudes toward learning, and improve retention and academic achievement (Behrens et al., 2010; President's Council of Advisors on Science and Technology, 2012; Vallim, Farines, & Cury, 2006). Many schools, however, still use didactic methods, which are widely regarded as failing to teach problem solving in an effective way (Director, Khosla, Rohrer, & Rutenbar, 1995). This is particularly a problem for engineering disciplines, where problem solving is a vital component of the professional practice. One reason that schools might be dissuaded from using PBL and community building is the relatively high resource cost of doing so with large classes.

Retention rates in many engineering programs are adversely impacted by the quality of the experience in the freshman year engineering courses (Canfield, Ghafoor, & Abdelrahman, 2012). Many schools struggle with the difficulty of developing ECE first-year curricula that are relevant and that stimulate student interest. First-year engineering classes in the ECE programs tend to be large lecture classes without hands-on engineering activities of the type that the students envisioned when they selected ECE as their college major. As a result, students become disillusioned and unmotivated; they fail to understand what engineers actually do, and what they can expect from a career in engineering (Canfield et al., 2012).

For students that do make it out of freshman-year courses, motivation is less of a problem, since by the second year they have already made the decision to persist in the degree. But by that time students face a different problem: lack of critical thinking and problem solving skills. The inability of students to do problem solving has been extensively explored and well described by Woods (1997), who argues that traditional didactic strategies, variously referred to as "sage on the stage", and "chalk and talk", are a large part of the problem because they fail to impart problem solving skills.

At The University of Houston, the honors engineering first-year experience is quite different. In those courses, the kinds of projects and classroom activities discussed above have been provided for several years. Indeed, survey data have shown that the honors students place great value on these activities (de la Rosa-Pohl, Habib, & Shattuck, 2013). However, the honors students are of a different demographic from those in the regular (non-honors) courses. They typically have higher entrance exam scores, come from better performing high schools, and are more competitive and self-motivated. Further, their classes are considerably smaller than the non-honors courses, so that their activities and projects can take place in the undergraduate electronics lab. Not surprisingly, the pass rate for the honors first-year courses approaches 100%, considerably better than that for the non-honors students.

There is, however, another crucial difference in the experience that honors students get: they are encouraged to feel that they are part of a special community, and that they belong to something that they can take pride in. That is, they are part of a learning community, which is built through a variety of group activities. These activities teach them that their immediate goal is to become a productive engineer, and help to give them a professional identity and purpose early in their academic career.

Hoping to build on the success of the honors program, a new hands-on first-year experience in ECE was created in the fall of 2013 at The University of Houston. The purpose of this paper is to present the preliminary results of that pilot course which scaled up the existing honors engineering first-year program. The implementation of PBL and learning communities in the new ECE course was based on best practices developed for the honors engineering program. The honors cohort served as a comparison group for the non-honors ECE cohort in this study in order to determine whether the methods used with the honors cohort would prove to also be effective with the non-honors population. Student survey data from the honors group had already been collected which showed that the methods used in the honors version of the course were well received and highly motivating (de la Rosa-Pohl, Goodwin, & Long, 2013; de la Rosa-Pohl, Habib, et al., 2013). Additionally, the use of the honors course as a model for the new ECE course improved the likelihood that the new project implementation would be successful. The justification for studying only ECE non-honors students is that the ECE department is currently the only engineering department at The University of Houston experimenting with a hands-on first-year curriculum.

Research Question

The engineering education literature provides evidence which supports experiential learning and community building as means to help students feel that they are connected with something exciting and relevant, and also to aid in developing the critical skills of professional practice. However, the authors of this paper wished to explore how scaling up a course designed for honors engineering students that combined both methods would impact large groups of non-gifted and talented engineering students. Therefore, the research question guiding this study was, *"How do attitudes and self-efficacy levels differ between honors and non-honors engineering students in a first-semester project-based course?"*

Significance

Although there is quite a bit of literature concerning the benefits of implementing evidence-based instructional methods such as PBL and community building in the classroom, there is considerably less literature addressing how these methods impact different populations within engineering. This research informs those curriculum developers who are either in the early stages of creating new first-year programs in engineering or who are thinking of scaling up current first-year programs to a different population. The project data may thus encourage the use of experiential learning approaches such as PBL, as well as learning communities in the broader engineering educational environment.

Methods

Intervention

Project-Based Learning. The experiential learning component of the intervention included (i) *projects*, which are the focal point of the course learning objectives, (ii) *in-class activities*, which were used as aids to learning concepts necessary to complete the projects, (iii) *practice and reflection exercises*, which were designed to enhance student skills, and (iv) *undergraduate teaching assistant support*.

The problem of supporting hands-on activities with a large class size was addressed using commercially available "lab-in-a-backpack" equipment. Use of the National Instrument myDAQ was explored with the ECE cohort, and was supplemented with equipment brought into the classroom, including various electronics parts: resistors, capacitors, light bulbs, diodes, and so on. Students were given a standard prototyping breadboard to use for activities and projects as well.

Projects served as focal points in each course; that is, the course learning objectives needed to be mastered to complete the projects. Projects focused on analog circuit analysis and computer programming.

The purpose of the projects was to teach skills in analog circuit theory and programming. More importantly, the projects served to motivate students to learn by providing context. Students were given the project several weeks before they were given the information needed to understand its operation. Thus, students had a context in which to understand the learning objectives. This process of discovery helped students feel that the course objectives, and their project work, was in fact relevant.

In-class activities served to illustrate ideas necessary to learning the course objectives. As the name implies, they were conducted in class by teams of two students. Teaching assistants circulated in the class to answer questions and helped troubleshoot the activities.

Practice and feedback assignments were given periodically to allow students to work on skills and to get feedback. These assignments asked students to do paper-and-pencil calculations, provide written answers to short questions, or carry out computer simulations. They were worked outside the classroom. Again, teaching assistants were available to answer questions.

Undergraduate teaching assistant support was available at the rate of approximately one teaching assistant for 15 students. Teaching assistants attended all classes and made themselves available during in-class activities. In addition, they held office hours in dedicated rooms during the week to answer questions, help students with the projects, and perform assessments.

Learning Community. Community building was done through professional development activities, team projects, and cohorts. In addition, in-class and out-of-class activities were designed to bring students together. The goal was to engage students in thinking about important engineering problems with peers.

Procedures

Data Collection

Paper surveys which measured self-efficacy and attitudes were administered to two cohorts of the ENGI/ECE 1100: Introduction to Engineering course at The University of Houston. Fifty-two students in the honors engineering sections and 101 students in the ECE sections (which included non-majors intending to enter ECE) were enrolled in the 1100 course in the fall of 2012 and fall of 2013 respectively. The surveys were administered during the last week of class, when all of the course projects were completed or near completion. Forty-three honors students completed the survey in the fall of 2012, giving a completion rate of 83%. Eighty-five students in the ECE sections completed the survey, giving a completion rate of 84%. Some students were willing but unable to complete the survey because they were not yet 18 years old and, therefore, needed parental consent to participate in a research study. Student responses were kept confidential and participation in the survey was completely voluntary. No benefits were provided to students for their participation.

Data Analysis

Survey responses were entered into SPSS 22 and analyzed. Descriptive statistics (mean and standard deviation) were calculated and compared between the honors and non-honors groups to determine if the intervention impacted the two groups differently. Because two means from independent groups were being compared, a two-tailed independent t-test was used to determine statistically significant differences and to reject the null hypothesis which states that there are no significant differences between the two groups.

Only survey items 12-23 and 30-50 were analyzed in this paper. All other items were not relevant to this study.

Results

Self-Efficacy Measures

In recasting the honors course to serve the general ECE population in a classroom environment, the instructors hoped to recreate the sense of community and engagement that had existed with the honors cohorts. Therefore, self-efficacy levels of the ECE students at or above those of the honors students would demonstrate that the success seen in the small laboratory used in the honors course could be replicated in a large classroom environment if appropriate mobile equipment and staff support were in place.

Figures 1 and 2 show a comparison of the student responses to survey items regarding self-efficacy. The first half of the ECE course covered basic topics in analog electronics and led up to building an infra-red detector circuit. Only the honors students eventually soldered the circuit because it was not feasible to bring soldering equipment for every student into a classroom setting for the non-honors group.

The data show that students in the ECE section showed remarkably similar results to the honors students on self-efficacy measures. The ECE students seemed to be just as confident in their analog electronics skills after working on the infra-red project. Only three items on the survey showed statistically significant differences. The honors students were significantly more confident in their ability to solder (Q23) and to use lab equipment (Q19). These data are not surprising since the honors students were the only group to work on the project in the electronics lab and eventually solder the circuit. However, the ECE students still showed on average a high level of confidence using laboratory equipment, even though they only used inexpensive mobile devices (such as handheld multimeters) in the classroom.

The third item to show a significance difference was the item related to calculating circuit values (Q16). It would stand to reason that honors students would be more confident in using their math skills to solve circuit problems due to their higher achievement scores in math. However, the honors students did not rate themselves significantly higher in generally applying their math skills to real-world problems (Q17). Therefore, it appears that the ECE students were less confident in the domain of circuit theory, even though they are all enrolled in an electrical engineering course. This result may be due to the open enrollment policy of the ECE course. Many of the students in the ECE course were not engineering majors, but instead students who were taking the ECE course to determine if electrical engineering was a good fit for them. And although most of the honors students were not electrical engineering students, all of those students were officially admitted into the engineering college at the time the course was taken. Therefore, the ECE course likely had more students who entered the course less prepared for a career in engineering and also less informed about the profession, which may have led to lower confidence on the theoretical side of electronics. Even so, both groups scored this item relatively high (honors: M=4.49, non-honors: M=4.17).

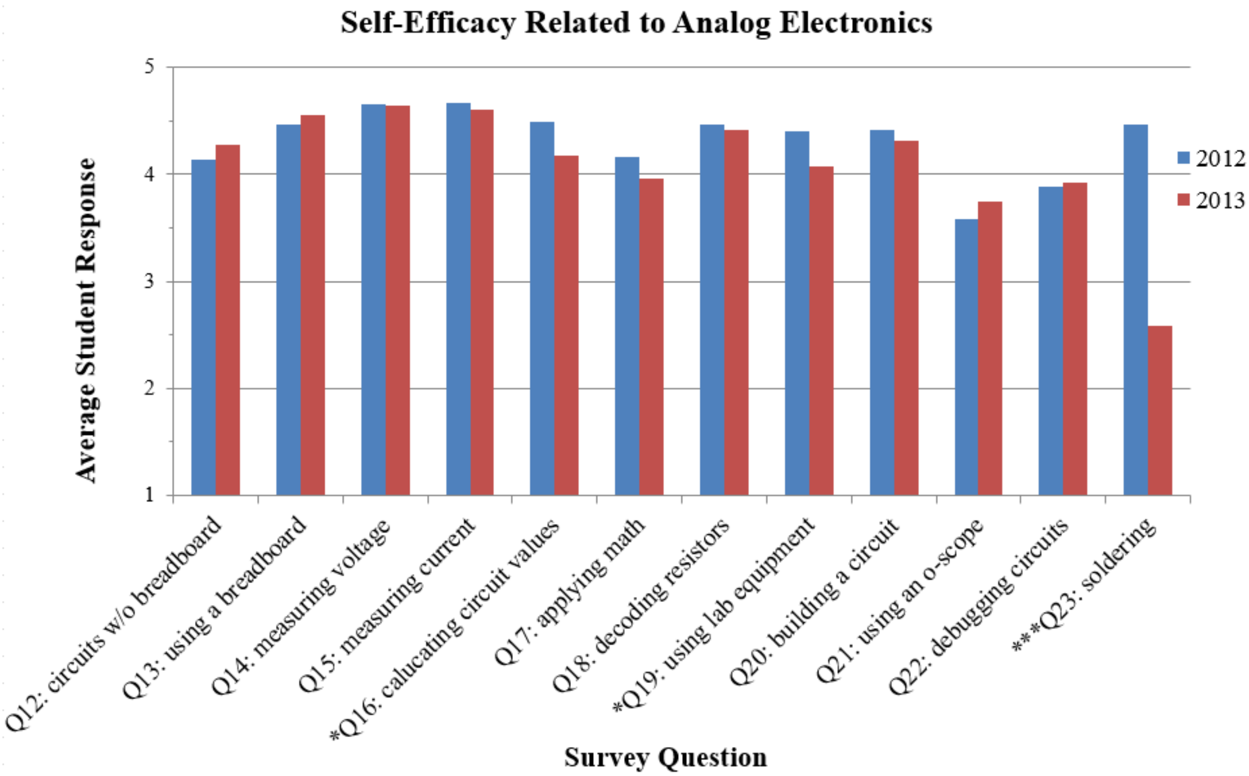

Figure 1. Students' perceived self-efficacy on items related to analog electronics. The 2012 cohort was the honors section, and the 2013 cohort was the non-honors section. A value of 5 represents high self-efficacy, and a value of 1 represents low self-efficacy. (*$p \leq .05$, ***$p \leq .001$)

The last part of the course was a programming project using the LabVIEW programming language. The entire honors cohort worked on a sumo-wrestling robotics project where completed robots competed in a sumo-wrestling competition on the last day of class. For the ECE cohort, only one third of the students worked on the robotics project. The rest of the ECE group worked on a programming-only simulation of the classic Simon memory game of the 70s and 80s. The difference in projects for the ECE students was due to limited equipment and lab space for the ECE students.

The data in Figure 2 show encouraging results regarding programming and teamwork. Even though the honors students had the advantage of participating in a living and learning community through the Honors College, the ECE group had similar high responses for teamwork even though many of them did not socialize with each other outside of class activities. The honors group did however show significantly higher scores on questions relating to robot building and research activities. These results are understandable since only the honors cohort participated in a research project (which required oral and written reports) and only a small portion of the ECE cohort completed the robotics projects. The lower scores for programming overall are to be expected since these courses are the first programming experience for many students.

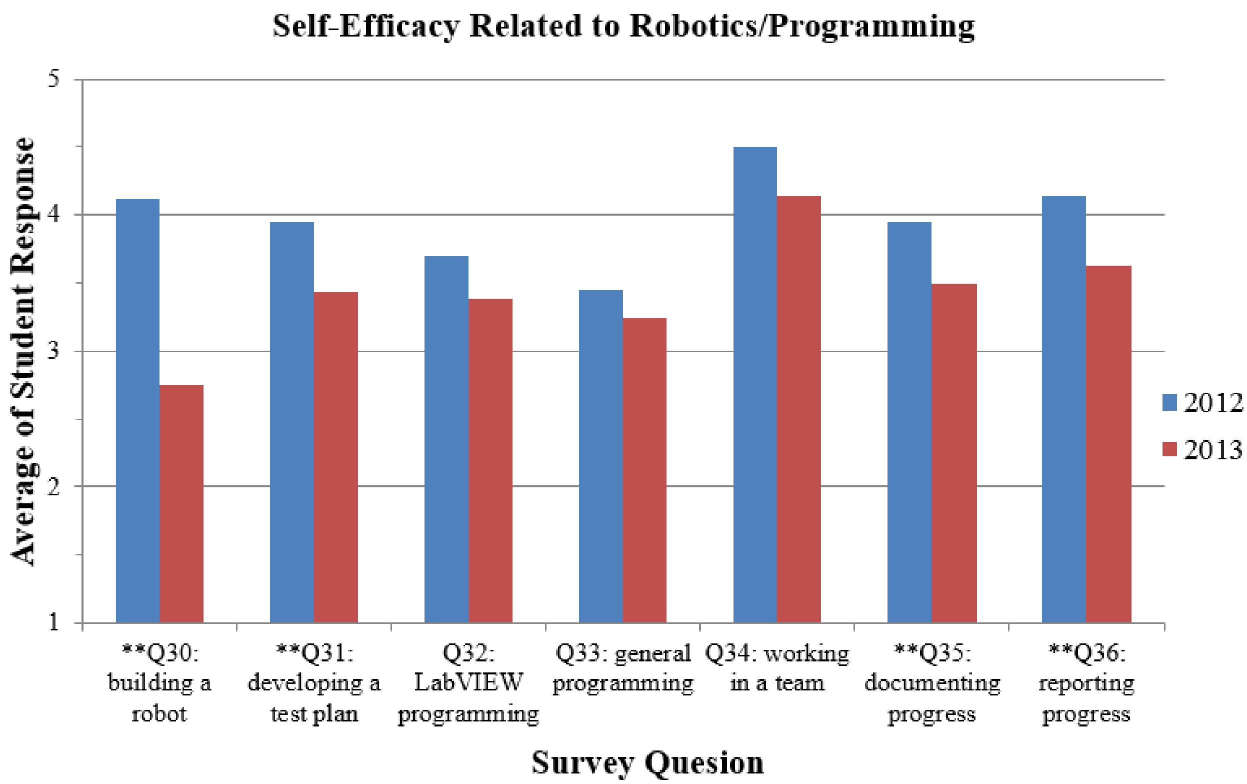

Figure 2. Students' perceived self-efficacy on items related to robotics and programming. The 2012 cohort was the honors section, and the 2013 cohort was the non-honors section. A value of 5 represents high self-efficacy, and a value of 1 represents low self-efficacy. ($**p \leq .01$)

However, the most notable result from these data is the similar trend overall on self-efficacy items. It again appears that the lack of a computer lab and a large class size did not adversely affect student confidence levels on course skills covered in the final project.

Course Impact

Survey questions 37-44 covered overall attitudes on engagement and persistence in engineering. These questions asked specifically about the impact of the course on those measures. The results show that only three items had statistically significant differences (Figure 3).

The non-honors students in the ECE section reported a significantly greater increase in commitment to engineering as result of the course. It may be that many of the honors students were already strongly committed, or it could be that there were many non-majors in the ECE section who were on the fence about a career in engineering and were swayed to switch to ECE. Both scenarios are favorable, and both cohorts rated that particular item (question 37) quite high.

The means for question 41 show that the honors students were slightly more likely to think about changing to another engineering discipline. Because even the multidisciplinary honors course was very heavy in ECE topics, some of the non-ECE honors students decided that they liked the material enough to switch majors to ECE. These students may explain this difference between the two groups. What is important to note here is that the means for both questions 41 and 42 are quite low (in the "disagree" to "strongly disagree" range) which means that after the first-year experience most of these students have the intention to stay in engineering.

The honors students also claimed to have formed more new friendships due to the course. This result may, however, be due to a spill-over effect from the living and learning community that all honors students participated in. The students may have been attributing the new friendships to the course, when in fact the new associations were being reinforced through activities within the honors program. There is not enough data in this study to tease out the Honors College effects, so it is impossible to know what really caused the honors students to engage more with each other.

Course Educational and Enjoyment Values

Figure 4 shows the average student responses for their perceived educational value and enjoyment value for each project (items 45-50 on the survey). Six of the eight items showed a statistically significant difference. One of the statistically significant differences was seen in the perceived educational value of the first project (analog electronics). The students were asked to build an infrared sensor which would output clicks on a speaker when infrared pulses were detected. The honors section (which was a multi-disciplinary group) found this project to be more educational and also more enjoyable (questions 45 and 48) even though the project was very heavy in electrical circuit theory. This was a somewhat surprising result as one would expect an electrical engineering audience to respond more positively towards an analog electronics project. One possible explanation for the difference is that the honors students were able to solder their sensors to produce a permanent device. The ECE group did not have access to an electronics laboratory for class, and therefore only built the circuit on breadboards. Perhaps the fact that the honors group had a tangible and working artifact at the end of the activity made this project more relevant in their minds. Assuming this to be the case, the ECE course instructors will make efforts in the future to include soldering (or wire wrapping) in the course, so that the ECE students also will be able to have a take-home artifact as a result of the project.

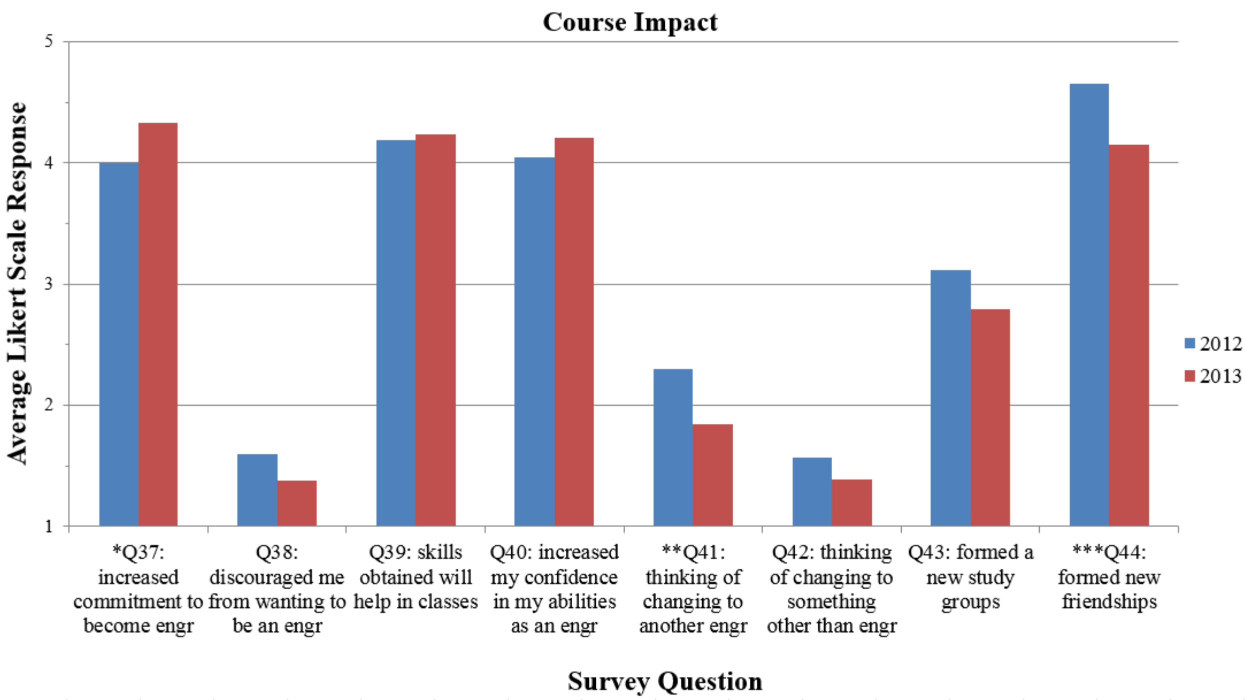

Figure 3. Students' perceived impact of the course. The 2012 cohort was the honors section, and the 2013 cohort was the non-honors section. A value of 5 represented strongly agree, and a value of 1 represented strongly disagree. (*p≤.05, **p≤.01, ***p≤.001)

The second project in the courses showed significant differences on both survey items (questions 46 and 49). This result is explained by the fact that the honors students had a research article as their second project, while the ECE students had another hands-on electrical project (digital-to-analog converter—DAC). In open-ended survey responses, the honors sections complained about having a long writing assignment in the course, so the lower project rating is not surprising. What is surprising, however, is how high the honors students rated the educational value of the project even though they did not seem to enjoy it. Even with the low enjoyment ratings of the project from the honors students, course developers hope to begin to add the research components back into the ECE version of the course so that students will obtain more research and writing experience throughout the curriculum.

And finally, differences were seen with the last LabVIEW programming project. Most likely the higher ratings from the honors section are due to the very different nature of their programming projects. The honors group and a small portion of the ECE group built sumo-wrestling robots as their final project. The rest of the ECE students (because the group was too large to work with in a computer lab) completed a purely programming project. Although both groups rated the project quite high on both measures, it stands to reason that the cohort in which every student worked on a highly engaging project (the fighting robot) would rate the project higher. Modifications are currently being made to the ECE version of the course to include a similar robotics project using a smaller and open-source platform which can be easily acquired by all students. The honors robotics project required access to a computer lab and expensive robotics kits for each team. A more economical and space-conscious solution will need to be developed for ECE students if they are to be required to work on the projects in a regular classroom.

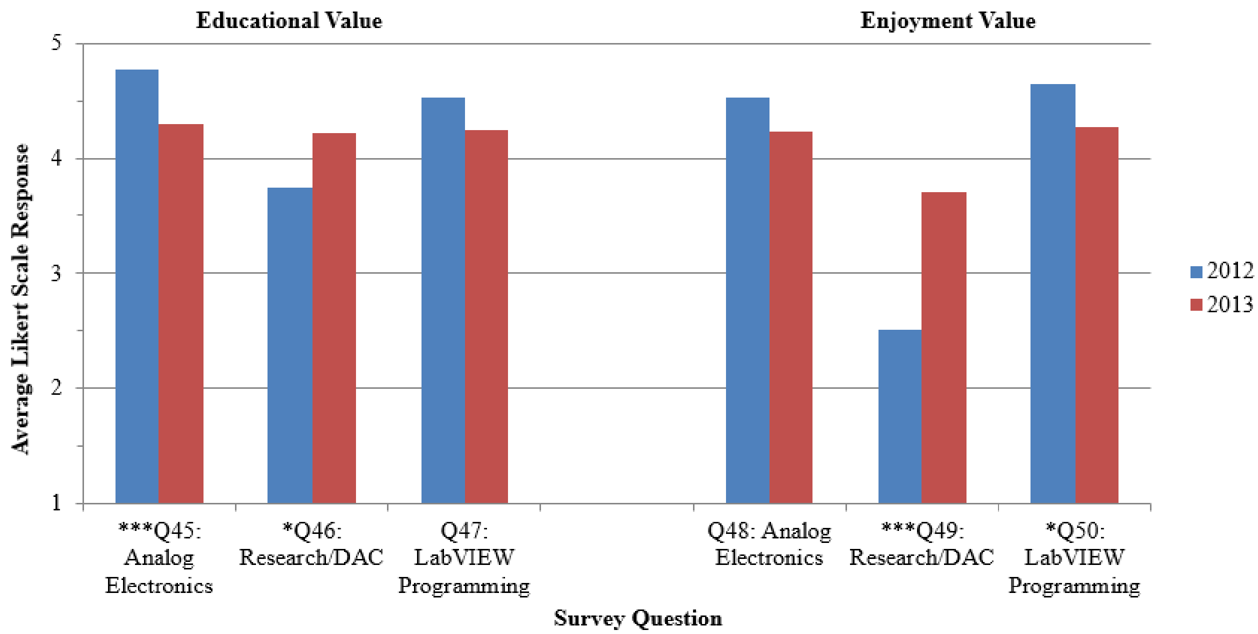

Figure 4. Students' perceived educational and enjoyment value for each project. The 2012 cohort was the honors section, and the 2013 cohort was the non-honors section. A value of 5 represented high educational/enjoyment value, and a value of 1 represented low educational/enjoyment value. (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$)

Discussion

The initial data from this study support the idea of using project-based learning and community building for both honors and non-honors engineering populations. Although the honors students do seem to be qualitatively different, those differences did not appear to be factors in the effectiveness of the instructional methods used in the courses surveyed in this study.

Initial data also show encouraging results for using large classrooms with mobile labs as an alternative to expensive instruments in space-limited electronics laboratories. Students are still able to achieve high levels of confidence in performing engineering skills even without the use of expensive laboratory equipment. The perceived levels of enjoyment and educational value also did not appear to be significantly impacted. These data also imply that large first-year experience programs can be effectively developed (even with large class sizes and regardless of student demographics) when proven research-based instructional methods are employed.

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