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Building Computational Thinking Skills Using Robots With First-Year Engineering Students

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Abstract

This research paper describes the transition of content in a first year experience (FYE) course at Mississippi State University (MSU) for computer science (CS) and software engineering (SE) majors to a project-based, hands-on approach to building skills in computational thinking and teamwork. While critical thinking ability and the dynamics of working in a team have been emphasized in the class through individual and team-based assignments previously, the use of technology has been limited.

Recent experience with a summer outreach program for middle and high school students suggests that students build confidence in problem solving by using a simple programming language with robotic concepts.[1] Building off of this experience, students in this first year engineering course were introduced to programming with a "drag and drop" interface and a robot. Teams were challenged to explore the robot's capabilities and brainstorm a project idea to design and implement. This project-based approach was expected to demonstrate an increased confidence in applying computing and technology among first semester students. Results of this first implementation are presented.

Background

Retention is an issue facing computer science departments throughout the United States. Many students begin their first semester of college with a declared major of CS, but transfer to other majors before graduation. For some, they realize that their interests and ability are not compatible with the major.[2] Biggers et.al. found that students who left the major defined CS differently than those who graduated in the major. Many students that left a CS major described it similarly to "the study of computer software" and "sitting at the computer with minimal human interaction."[3] Studies conclude that many students do not consider selecting CS as their major due to a lack information about the coursework and career opportunities.[2, 4]

The Computer Science and Engineering (CSE) department at MSU introduced an introductory seminar format course in fall 2010 in an attempt to provide missing information about CS and debunk misconceptions. Academic and industry guest speakers frequent the classroom offering a view into the types of careers available and the ways that computing is used in a variety of domains. A technical writing class session is facilitated each semester by a writing instructor, and is followed up with writing assignments. CSE 1002 Intro to CSE is open to freshmen CS and SE majors and is offered only in fall semesters. Objectives of the course are defined as:

- Enhance understanding of the CS and SE academic majors,
- Develop team building skills and encourage group participation,
- Develop computational thinking skills,
- Provide an awareness of ethical issues unique to computing,
- Provide an understanding of the history of computing, and
- Develop an awareness of the career opportunities available to computing majors.

Experience with summer computing camps for high school and middle school students has demonstrated that using a robot-based curriculum helps increase confidence in the use of technology.[4] Skelton et. al. conclude that students that are familiar with robotic concepts and a very simple programming language prior to entering college are at an advantage[5.] While this first year course is taught after the student has entered college, it is experienced by all entering CS and SE freshman in their first semester. By offering a hands-on experience with a simple programming language and robotics in this initial class, students without the benefit of prior exposure to the application of technology gain that experience. Hall and Mungar summarize that robotics have become a popular addition in first year experience courses for computer science and engineering because the physical aspect of a robot makes the computing process explicit and motivates students to learn.[6]

Many first-year college students are lacking in confidence and may be intimidated by a college-level project.[7] Montgomery surmises that small, tightly defined projects may not provide the scope that students need to develop more self-confidence in their ability to solve problems with technology through programming.[7] Hauer and Daniels suggest open ended group projects (OEGPs) as a way to motivate higher order thinking skills in students. They argue that providing learning experiences with loosely-defined problems in an educational setting better prepares students for the types of problems they will encounter in the professional world.[8] A student-driven design project offers the opportunity for a "significant experience in problem specification and engineering design"[9] and leads to deep learning.[10] Freeman et. al. found that a hands-on project experience can provide a context that helps facilitate a student's pathway to engineering.[11]

Project Description

Twenty percent of students that completed CSE 1002 in fall 2015 were African American, and 18% were female. Some of the students, due to ACT math sub-scores, were enrolled in college algebra or a remedial math class. Those students are unable to take the introductory programming class until college algebra is completed with a grade of C or better. A smaller set of students in the class entered the university with college credit equivalent to the first or second programming class in the curriculum sequence. Some students learned some computer programing through high school clubs or on their own before college. Most of the students in CSE 1002 were co-enrolled in the introductory programming class.

CSE 1002 has emphasized critical thinking and teamwork since the course's inception, but the use of technology has been limited. The intent has been to place more emphasis on problem solving, critical analysis, and group dynamics[2]. Student feedback in prior semesters revealed the need for a more 'technical' component in the class that would challenge the more experienced students but introduce and enable an increased confidence with technology and programming for the more novice students. To help increase confidence with problem solving and programming, an eight-week team project using a Finch[12] robot was assigned. With similar projects reporting frustration among students when the robot used has to be assembled by the students[6], the Finch robot was chosen for its advantage of being already assembled, without multiple parts that can be lost or damaged. The Finch enables students to focus on the software design rather than constructing the physical robotic device.

Objectives of the project assignment were presented to students at the beginning of the project. In addition to exposing students to programming and critical thinking, soft skills experience was also a goal. The project objectives were presented to students as follows:

- building skills that enable effective teamwork,
- working with loose structure,
- exercising creativity, and
- developing and exercising algorithmic thinking skills.

The project objectives of teamwork and thinking skills directly support the course objectives defined earlier. 'Working with loose structure' and 'exercising creativity' are intended to support the approach of OEGPs as suggested by Hauer and Daniels[8] and provide the opportunity for students to work independently on a student-driven design.

Similar to the approach described by Sun and Grant[14], students in this FYE class were required to decide what they wanted to program the Finch to do and how they wanted to implement that idea. Students were allowed to self-select teams, and instructor team assignments were made for students who did not have a preference. Teams consisted of three or four students. Due to some students withdrawing from the university or the class, a few of the teams ended with only two participants. One Finch robot was shared by each team.

The project was supported by a team of mentors hired through the Bagley College of Engineering (BCOE) to enhance the first year experience of engineering majors. Three undergraduate mentors supported this project. Mentors led class sessions on programming the Finch, and provide lab assistant type support on class days designated as project work. Mentors also posted office hours and contact information so that students could reach them outside of class. For class time project work, two smaller classroom spaces were reserved to enable closer interaction between the mentor and the participants.

Programming a Finch can be simple and easy for a novice to learn, yet it can also be exploited by a student with more experience. Those more experienced with applying technology were able to push the limits of their current abilities and use a higher level programming language. Students were advised that higher level programming languages could be used, but to do so required the team to research the development environment required and traverse that learning curve independently. While most of the teams chose to use Snap![13], a few teams implemented their project using Java, Python, or C++. Implementations ranged from having the robot play the school's fight song, to having it traverse a complicated maze that the team constructed, either following a light or by sensing a wall and changing course to continue. At the end of the semester, teams presented their projects to class members, the instructor, and mentors.

Project Assessment

Each team was required to demo their project during class. In addition, each student was required to submit a one page report with the following elements:

- What the robot was programmed to do
- What the student learned from the project

With the knowledge that skill levels in the class covered a wide range, projects were not graded comparatively in terms of level of difficulty.

Pre- and Post- surveys were distributed to assess the students' perception of technology and their self-rating of ability to apply technology at the beginning of the project and at the conclusion of the project. There were 95 students enrolled at the beginning of the semester. Following the typical class drop and withdrawal period, a remaining 87 students embarked on the project and completed the pre-project survey. Some of those 87 did not complete the course successfully, with a total of 80 completing the post-project survey.

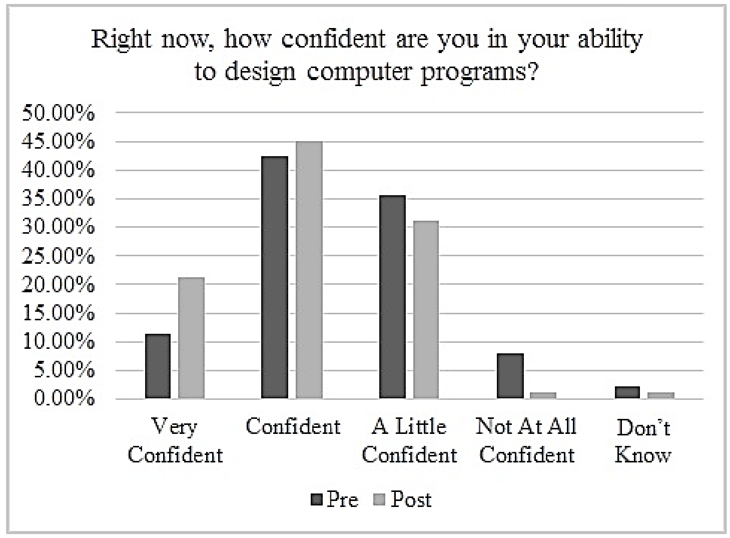

Figure 1. Program Design Confidence

Pre- and post- results from survey questions are depicted in Figures 1-5. Figures 1 and 2 show the students' perception of their confidence level in designing and writing computer programs. The numbers of those 'not at all confident' was reduced, with more students expressing confidence in design and programming.

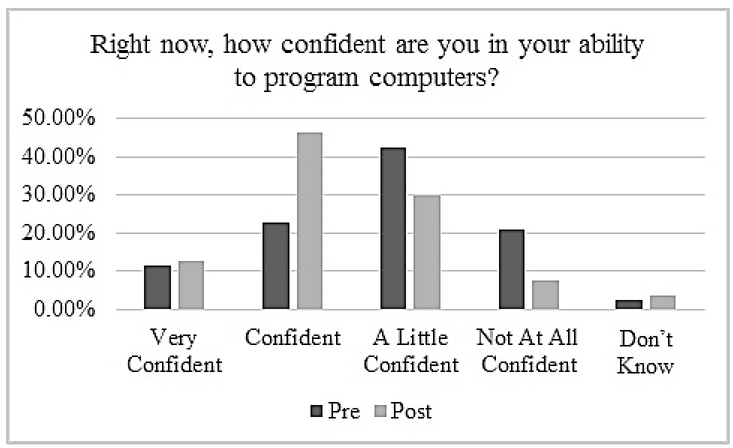

Figure 2. Program Writing Confidence

Figure 3 below reveals an increase in confidence level for students' ability to use computer software. Students were introduced to the Snap! programming interface in class, but were responsible for installing the necessary components to use the interface on their laptops. Many teams reported challenges with getting the Snap! interface working so that the Finch could be programmed, and many reported issues with getting the Finch to behave as intended when the robot's sensors were used. Teams worked through these issues among themselves and sometimes with the guidance of the student mentors.

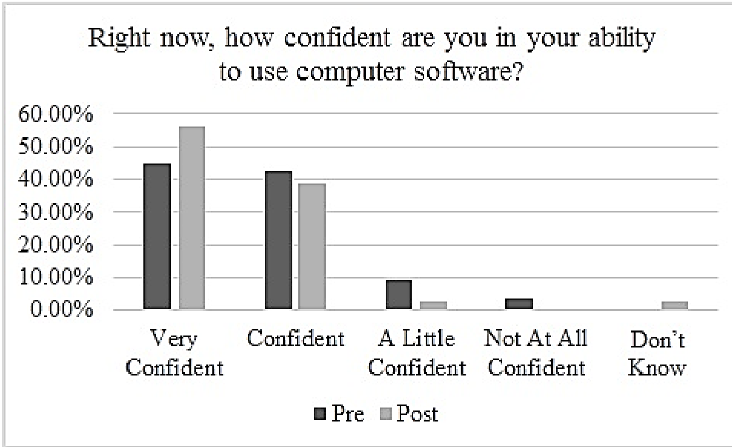

Figure 3. Confidence in Using Software

Students were asked about their confidence in thinking of new technical inventions and their ability to implement those ideas. Results of those survey questions are summarized in Figures 4 and 5. Results indicate that some students did not feel confident in their ability to construct a technical vision or successfully implement that vision. When asked verbally by the instructor what the most challenging part of the project was, many students reported that thinking of something to do with the Finch was the hardest part, indicating that the creative aspect was more challenging than the technical part.

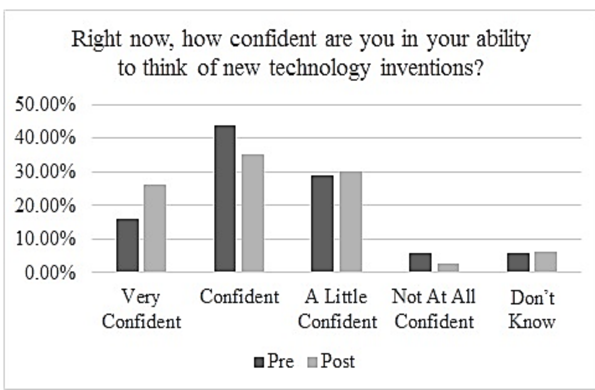

Figure 4. Confidence in Envisioning New Technology

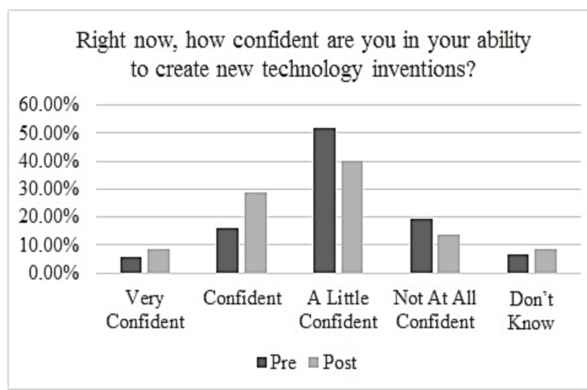

Figure 5. Confidence in Creating Technical Inventions

In addition to the questions described above, both surveys asked an open ended question. The pre-survey asked what the student was hoping to learn with the robot programming project, and the post-survey asked what the student did learn on the project. Some of the comments from the post-survey are indicative of feedback received verbally by the instructor. Many responses indicated that the project was beneficial and educational. A few of the post-survey responses are shown in Table 1.

Table 1. Sample Post-Survey Responses

- "What I got from this project was better group skills and learning to work independently as well as voicing concern and ideas within a group."
- "Programming a robot is nothing like what I have ever done before, and it gave a sort of substantiality to what I have learned throughout my intro programming class"
- "For me, this project was also my first experience with applying programming concepts to the real world."
- "This project also taught me that developing a good program is best done with the consultation of others. Having other people develop a program with you gives you even more options to make your program more effective."

Other comments revealed additional experiences gained among the students. Some students were able to rise to a position of leadership within their group, while others were exposed to the experience of having to ask for help. One student indicated he took the role of team leader and helped facilitate communication among team members so that they could aggregate their independent knowledge to further their group. Another two students came to the realization that there was nothing wrong with learning from others; both students were able to learn from one another. Additionally, some who indicated they were originally reserved about speaking up found a safe environment in their team where they could offer ideas and contribute to the group. Many noted that their time management skills were exposed, citing the downfalls of waiting too close to a deadline to finish a project.

Conclusion

With the varying backgrounds and status in the curriculum among the class participants, it is hard to measure from these results whether the Finch programming project alone impacted the perceptions of every student. Some students were simultaneously enrolled in the first or second programming class in the curriculum, which would also have likely influenced their responses early and late in the semester. From the survey responses presented above, and particularly from the free-form comments, the project did appear to have a positive impact on the participants.

Future Work

This project will be continued and measured in upcoming fall semesters. Instead of having a robot assigned to each team for sharing, students will be required to purchase a Finch robot, which retails for $99[12]. No textbook is required for the course, so the robot will be the only necessary purchase. The intent of this requirement is to ensure that each student has the opportunity for hands-on work with the Finch without balancing use of the robot among team members. One or two individual assignments will be added, but the semester project will still be team-based.

The pre- and post- anonymous surveys will be expanded to include additional data about the student. This data will include ethnicity, gender, and prior exposure to programming including current enrollment. This will enable further analysis into the impact of this project for students in underrepresented groups. It will also be useful to know if students are impacted more by this project if they are not enrolled in another computing class at the same time. Participants will also be asked to provide an identifier that will enable a paired t-test analysis.

In addition, an approach to teaching C programming to non-CS majors in a service course will be piloted based off of this first-year experience course project. Similar data will be collected to measure effectiveness.

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