Board 52: Cultivating the Maker Culture through Evidence-Based Pedagogies

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WIP: Cultivating the Maker Culture through Evidence-Based Pedagogies

This is a work in progress paper.

1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) fields are essential to America's economic growth and global competitiveness. However, there is a mismatch between the supply and growing demand for STEM-skilled workers. According to the 2016 White House Report [1], there were over a million unfilled jobs in information technology across all sectors of the economy. The STEM workforce has grown faster over time than the overall workforce, the projected growth rate for STEM occupations from 2014 to 2024 is 8.9%, which is higher than that of non-STEM occupations (6.4%) [2]. Specifically for computer related occupations, the projected growth rate is 12.5% from 2014 to 2024 [3]. And the 2018 White House Report [4] points that, "although women make up half the population, they comprise less than 30% of the STEM workforce; and similarly, underrepresented racial and ethnic groups make up 27% of the population but comprise only 11% of the STEM workforce." This adds up to the existing socio-economic gap between men and women, and between the ethnic minorities and the European-Americans in the society.

Specifically for the computer related technology, along with the dramatic advancement of the recently emerged technologies, industry is in great need of graduates with computing-related majors. The U.S. Bureau of Labor Statistics forecasts that, by 2024, there will be 488,500 more jobs created, which will end up with 1,083,800 total job openings in this category [3]. Due to the aging workforce and emerging techniques [5, 6], industry demand for the qualified graduates with expertise in computer science and computer engineering and technology is tremendous. However, recruitment and retention rates for computing disciplines in the U.S. are dropping, especially for the minority serving institutions. The shortage of the qualified computer-related workforce in the U.S. and the challenges from rapidly growing countries, for example, China and India, have resulted in more computing jobs being shifted abroad every year. This tendency will cause the U.S. to gradually lose its lead in the computer industry. Furthermore, studies have shown that computing classes frequently teach students outdated content that is not relevant to current technologies [7, 8]. As a result, computer related majors have been reported by many institutions to have high drop rates and low enrollment among females and minorities [9, 10].

The advances in computer technology and the use of the mobile computers and other available communication devices that connecting to the Internet have drastically changed our daily lives and some portions of our lifestyles. People can easily acquire information regardless of their location. Easily accessible hardware, for example, sensors and cheap microcontroller boards, provide more methods of doing things without the need of complicated tools or direct aid of experts or professionals. However, the teaching of college level computer related courses has not changed much. This enlarges the gap between the advanced computing technology students experiencing in their daily lives and the outdated college level computing education. In fact, those students who choose computer related programs as their majors are attracted by exciting computer applications. However the traditional classroom teaching style does not fit their learning styles.

To tackle the abovementioned problems, a team of engineers and learning scientists in two universities has been working on a collaborative grant project funded by the Department of Education for the purpose to enhance the student diversity in STEM fields. In this project, we aimed at (1) contextualizing the student learning experience in STEM fields, and (2) implementing an integrated STEM education approach to teach the skills and knowledge that are necessary to be competent in engineering and technology careers in 21st century. The research objective of the present study is to investigate the effectiveness of evidence-based instructional strategies and the integration of the maker culture on students' problem solving and life-long learning skills. Specifically, we introduce evidence based pedagogy together with maker culture into our STEM courses to increase the enrollment as well as the retention rate of underrepresented students, including females and minorities. This improvement of teaching infrastructure and pedagogy at a minority serving institution will significantly enhance the teaching quality and eventually will have a positive impact on the US's economy and well-being.

The main question that will guide the investigations of this study is: "What are the effects of the contextualized and student-centered instruction in computer science courses on students' learning outcomes and experiences?" This paper reports our planned activities that will be implemented in Fall 2019 semester.

2. Background

How People Learn (HPL) framework [11] and the student-centered instructional strategies informed the design of our project activities and our instructional efforts. We implement evidence-based pedagogies in core engineering courses in order to improve our students' engagement and expertise as future makers. Instead of working in a theory-centered environment, we are working to explore contextualized and student-centered teaching approaches that allow students to learn by making. A review of literature suggests that contextualized instruction enhances students' interest and engagement in the content being taught [12], [13], [14]. Maker movement and maker culture will be introduced to the classes. Students will be guided to get familiar with the maker space and maker tools. Engineering faculty will work with the project team to design the new teaching modules that are student-centered and informed by the HPL framework [11]. Meanwhile students will learn how to use the tools and gain confidence to become "makers" in the engineering community.

How People Learn (HPL) Framework: Research has shown that an ideal learning environment is characterized as (a) knowledge-centered, (b) learner-centered, (c) assessment-centered, and (d) community-centered [11]. Evidence-based pedagogies are often the ones that are student-centered, and learner-oriented.

Maker Movement: As explained at techopedia.com, the maker movement is "primarily the name given to the increasing number of people employing do-it-yourself (DIY) and do-it-with-others (DIWO) techniques and processes to develop unique technology products. Generally, DIY and DIWO enables individuals to create sophisticated devices and gadgets, for example, printers, robotics and electronic devices, using diagrammed, textual and or video demonstration. With all the resources now available over the Internet, virtually anyone can create simple devices, which in some cases are widely adopted by users." The maker culture emphasizes informal, networked, peer led, and shared learning experiences motivated by fun and self-fulfillment [15]. The maker culture emphasizes hands-on skills and learning-through-doing in a social environment. These skills and learning philosophies especially fit the teaching/learning objectives for engineering and engineering technology students. With students becoming more increasingly disengaged from STEM subjects in formal educational settings, introduction of a maker culture to the classroom has the potential to create new pathways into topics which will make computing more interesting and attractive to learners.

Life-long Learning: Lifelong learning is the "ongoing, voluntary, and self-motivated" pursuit of knowledge for either personal or professional reasons. Therefore, it not only enhances social inclusion, active citizenship, and personal development, but also cultivates self-sustainability, as well as competitiveness and employability [16], [17]. In the engineering job market, hardware and software are constantly being updated to meet industry needs. New graduates have to be capable of learning new material on a yearly or even monthly basis. What the students have learned in the classroom during their studies will soon become out of date and in some cases obsolete. Students have to develop skills to learn independently. The nature of engineering careers requires students to have a life-long learning vision and self-motivation.

3. Study Purpose

In this study, we aimed at improving students' learning experiences and outcomes through contextualized and student-centered activities in computer science courses. To answer the main question of the study, maker culture will be cultivated in the participating courses in Fall 2019. A Mini Maker Faire at the main institution will be held for all students in the college of engineering to showcase their final projects from their courses. These activities will be held in 2019 and 2020 academic year. In this paper, we report the work in progress and describe our project activities.

4. Study Context: Participating Courses

This project will cultivate maker culture in different computer science courses. Below is the description of each course, its current teaching context, and how the project will potentially impact the course context.

ELEG 4253 Embedded Systems Design is a three-credit lecture course. It introduces the architecture, operation, and application of microcontrollers. Topics cover both hardware interfaces and software programming, including, CPU addressing decoding, memory hierarchy, I/O interface, and interrupts. At the completion of the course, students will be able to develop software to control applications interfacing with microcontroller; manage memory and I/O systems; and explain the differences among microcontroller families in the current market. Currently the course is taught in a traditional way. Students read the assigned textbooks and they follow the taxonomy of the books in class. Take-home work is assigned to students to review the course contents. Quizzes and mid-term exams are adopted to evaluate the students' content understanding. As computer technology is one of the fastest growing areas in the past several decades, various applications are widely used in our daily lives, yet not published in books. The instructor is going to expose students to the competition tasks and lead students to search for technical solutions through student centered class projects for the purpose to cultivate the maker culture in the course.

COMP 3013 Embedded Systems is a 3-hour lecture course. Students learn about the modern digital design methodologies, microprocessor operations, arithmetic operations, software programming, hardware interfacing, and microprocessor based system design. At the completion of this course, students are expected to understand the basic concepts of software architecture of microcomputers and become familiar with hardware architecture of microcomputer and microcomputer interfacing techniques. In the new course context, the students will be asked to design and make their products. The products can be proposed for a competition or for personal use. The instructor will make sure that the projects are appropriate and related to the courses. Students will be encouraged to work in teams and they will be expected to share the information within and across the teams. All students will be familiar with maker space and maker tools. Their products will be showcased in the Mini Maker Faire.

ESET 359 Electronic Instrumentation is a four credit hour required junior level course. Students taking this course are required to pass the following courses: embedded system development in C, digital electronics, microcontroller architecture, circuit analysis, and analog electronics. It is a pre-requisite for the control systems course. The course is currently delivered in a traditional way of three hours of lecturing and three hours of laboratory each week. In this course, students learn the general concept of measurement systems, virtual instrumentation using LabVIEW, sensors, analog to digital converter, digital to analog converter, sampling theorem and aliasing, digital filter design and analysis, and signal conditioning circuits. There are typically seven laboratory exercises and a course project, where some kind of LabVIEW or microcontroller based measurement system is designed, fabricated, and tested. At the completion of this course, students are expected to be able to design a data acquisition system involving sensors, LabVIEW, microcontroller programing, and printed circuit board design and fabrication. This course will be revamped according to the proposed evidence based pedagogy with maker culture introduced. Student-centered teaching modules and activities will be designed. A high impact-learning environment will be created in ESET 359. Students in this course will participate in selected maker events and competitions. The focus area will be in PCB design, sensors, and embedded system development. Examples include development of wearable embedded systems, electronic clock, and autonomous robots. The ESET program will sponsor a maker event in the Product Innovation Cellar (PIC), which is the space used by ESET students to work on their capstone projects and other product development related work. Surveys will be designed and conducted in the beginning and end of the semester to ESET 359 students. The objective is to measure their knowledge level and interest in embedded system development. Before-and-after analysis will be conducted based on the survey data. The result will be compared to that from the CPET surveys.

5. Extra Curriculum to Promote Maker Culture

We have organized robotics clubs and ACM student chapter activities in the authors' departments. With the success of fostering maker culture in the courses proposed in this project, students will be familiar with maker culture and the maker tools, and ready to make more sophisticated projects. We will work closely with the students in designing these projects and showcase the products in the mini maker faire. These clubs and organizations will be the spark to light the STEM interests of all students in the College of Engineering. The findings and data collected from the students' activities will be also analyzed by the learning scientist and provide a close loop feedback to both the enhancement of the clubs and the improvement of the in-classroom teaching.

6. Data Collection and Analyses Plans

To explore the impact of the contextualized and student-centered instruction on students' learning outcomes, we will ask students to complete a demographic questionnaire, a lifelong learning scale, and a student experience survey. These instruments will be administered in the courses in Fall 2019. We are collecting data from courses STEM faculty teach in Spring 2019 using a demographic questionnaire and the lifelong learning scale. The data collected will be used for control purposes. The differences between the data collected in Spring 2019 and Fall 2019 will help explain the effect of the contextualized and student-centered instruction on students' lifelong learning skills and content understandings.

7. Conclusion

The design and implementation of the contextualized and student-centered instruction (that are student centered and HPL framework informed) will be in Fall 2019. In this paper we reported the summary of our project and described our data collection plans from the students. Our project will help improve STEM faculty's awareness of evidence-based pedagogies and willingness of using these pedagogies. Evidence-based maker culture teaching modules that we develop and test can be used in other STEM courses. Our students' learning, interest, and retention in specific subjects will be improved. The number of ethnic minority students, particularly minority women, in STEM fields will be increased.

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