Work in Progress - First-Year Programmers Developing Software Applications for a STEM Academy Workshop: An Exercise in Collaborative Service Learning

John K. Estell, David Reeping, Heather Sapp, Alexandra Seda
Ohio Northern University, j-estell@onu.edu, d-reeping@onu.edu, h-sapp@onu.edu, a-seda@onu.edu

Abstract – **In an effort to provide assignments with practical implications, teams in a second semester introductory programming course were tasked with developing a software application based on lesson plans written by engineering education students enrolled in an Engineering Projects in Community Service course. In 2014, the lesson plans were created for STEM-oriented continuing education workshops for teachers in the Dominican Republic, and the applications were intended to serve as a distance education equivalent. Despite the students reporting generally positive experiences, user testing and constructive feedback proved to be difficult. As a result, the 2015 offering of this project was heavily reworked to support local STEM outreach activities for fourth through sixth grade students. This work in progress paper describes the premise of the assignment, the recent revisions made, and initial reflections on the effectiveness of the new approach.**

Index Terms – authentic assignments, first year engineering, programming, service learning

INTRODUCTION

Among the various challenges of teaching in the first year, providing students with meaningful experiences is particularly difficult. One approach is to use authentic learning, where knowledge is applied in real world contexts. Through the qualitative content analysis of forty-five relevant journal articles from different disciplines, Rule outlined four characteristics of authentic learning [1]. First, the problem at hand is rooted in the real world, and the solution to the problem has the potential to make a measurable impact on people outside the course. Second, learning is achieved through the application of higher-level inquiry and thinking skills, such as those found in Bloom's Taxonomy [2]. Third, authentic learning occurs through working within a community of learners. Fourth, students must be empowered in some way, such as by providing an open-ended assignment.

Projects with more relaxed constraints in the context of authentic learning can benefit from the repeated application of Kolb's Experiential Learning Cycle, where learning is understood to be a continuous process of framing and reframing experiences [3]-[4]. The learning cycle consists of four distinct states. In the *concrete experience* state, the student is fully immersed in new experiences. In the next state, *reflective observation*, the student reflects on the experiences from multiple perspectives. *Abstract conceptualization* follows, where the student formulates concepts that integrate their observations into theories. Finally, the theories are used to make decisions and to solve problems through *active experimentation*. The cycle is then repeated as new experiences are attained.

One successful approach of combining authentic and experiential learning involves engaging students in service learning activities [5]. The effectiveness of this methodology can be explained by the tendency of students to look for careers with meaning. Providing opportunities for first-year students to find meaning within their chosen major can aid with retention; unfortunately, a survey of 200 introductory-level assignments within leading computer science programs revealed that only 34% of the assignments had a practical or socially-relevant context [6]. Much like authentic learning, there are guiding principles, such as those offered by Weigert [7], which involves the student providing meaningful service that meets a community-defined need and the service itself flows from course objectives. Ideally, the service is integrated into the course by means of an assignment requiring some form of reflection.

Within the context of engineering, service learning often manifests itself at institutions as an Engineering Projects in Community Service (EPICS) course [8]. EPICS is offered as a multiple section, one credit hour course at Ohio Northern University. The focus of the EPICS program is on the community partner, the person or group who determine the criteria and constraints through the conception of the project. For the assignments described here, the community partners are involved in STEM-oriented educational outreach opportunities.

Another avenue toward authentic learning involves the intersection of engineering and entrepreneurship. Growing interest in instilling an entrepreneurial mindset in students has led to a variety of engineering programs and courses delivering such outcomes [9]-[12]. The Kern Entrepreneurial Engineering Network (KEEN) is one of the leaders in promoting collaborative efforts among American private universities to nurture the entrepreneurial mindset in undergraduate engineering students [13]. As with any new endeavor, assessing the attainment of the related course and program outcomes is desirable in order to both determine successes and to learn from failures [14]-[16].

The typical first-year student often possesses only a portion of the skill set necessary in order to fully contribute to a service learning experience; this is especially true in the computing disciplines. However, by using an external group directly involved with a service learning project as their client, it was hypothesized that first-year programming students could gain some of the benefits associated with service learning, even though they are only playing an ancillary role in the service effort and do not travel to the site of the project. Thus, in the offering of Ohio Northern University's Programming 2, a second semester introductory programming course, the investigators designed a term project [17] that featured experiential and authentic learning through use of a real-world client.

PRIOR WORK

Previous research has examined to what extent first-year programming students can achieve outcomes associated with service learning experiences via a culminating term project [17]-[19]. Programming teams were charged with developing a Java-based software application for clients – a group of engineering education majors – enrolled in an Engineering Projects in Community Service (EPICS) course. The engineering education students' project involved developing lesson plans for STEM-oriented continuing education workshops for teachers in the Dominican Republic; however, these lesson plans were already completed prior to the collaboration with the introductory programming students. Each programming team needed to develop a software application that supported one or more of the learning objectives of their assigned lesson plan. The EPICS students would then conduct these lessons during a service trip in the Dominican Republic and provide links to the software applications as a distance-learning supplement [20].

Assessment of the first-year programming students through use of the Community Service Attitude Scale (CSAS) instrument [21] showed several statistically significant indicators of positive attitudinal adjustment within the 10 attitudes that it measures; however, several areas for improvement were noted, including greater team-client collaboration, increased development time, and a better understanding of the needs of the customer [17]. Moreover, performing user testing and obtaining constructive user feedback proved to be difficult. While it was relatively simple enough to create and distribute a website containing all of the applications, gathering constructive criticism persisted as a challenge – a cultural characteristic that was noticed when conducting prior STEM-oriented workshops in the Dominican Republic [20].

REIMAGINING THE ASSIGNMENT

With consideration to the areas for improvement, the Spring 2015 term project for Programming 2, while still resulting in a Java-based software application as its deliverable, was considerably reworked in three distinct areas: client dynamics, audience, and assessment.

I. Client Dynamics

The original EPICS course ran during the Fall 2013 semester; consequently, the lesson plans for the programming students to turn into applications were completed before the programming project was assigned. As a result, there was little guidance for the programming students, nor feedback for the EPICS students. In the qualitative portion of their post-activity surveys, the programming students reported that a communication gap existed between their group and the engineering education students. This was primarily due to the manner in which the interactions were facilitated: one student from the EPICS course served as the line of communication between the two groups by delivering written feedback and evaluation scores, with questions handled through email. To address this shortcoming, during the 2014-2015 academic year the EPICS course was offered as a special topics course in lesson plan design and was run in parallel with the second-semester introductory programming course, thereby allowing the software applications and lesson plans to be integrally developed as part of a true collaborative effort. Additionally, the structure of the assignment was refined such that several of the KEEN entrepreneurial mindset outcomes could be attained in both the introductory programming and special topics courses. To enhance both collaboration and communication, each lesson plan's author became the client for whichever team the lesson plan was ultimately assigned. In the previous year, the authors of the lesson plans had little to no interaction with the programming students; therefore, the brainstorming and concept development heavily weighed on the programmers. Accordingly, in 2015 the student-clients regularly visited the programming teams during scheduled lab and lecture times in order to better interact with their assigned teams.

II. Audience

To create a greater sense of connectedness, and with hopes of collecting constructive end-user feedback, the target audience was changed from teachers in the Dominican Republic to local fourth-, fifth-, and sixth-grade students participating in a STEM Academy workshop conducted annually by Ohio Northern University's ASEE Student Chapter. Choosing such an audience allows for the lesson plans and accompanying software applications to be more readily developed via the constraints provided by both the Common Core and Next Generation Science Standards. As the focus of the lesson plans is to supplement the teaching of Mathematics and Science while promoting the importance of Engineering, teams were charged with creating additional value for their lesson plan by developing an interactive and engaging software application. By tying into published standards, it is hoped that teachers will be more inclined to use these applications during class time. Additionally, the students targeted by this outreach are at the start of the age range in which the differences in learning levels for Mathematics and Science become more apparent. This in turn increases the value of the deliverables in the eyes of the participants due to the possibility of making a difference in the lives of others. Finally, the Programming 2 students can more easily participate in the subsequent delivery of these lesson plans, thereby providing additional positive feedback opportunities from the end users.

III. Assessment

In Spring 2014, each programming team's deliverables were assessed using a set of traditionally formatted rubrics created by the EPICS course participants and by the instructor [17]. Teams were required to submit a proposal, which was then evaluated by students from the EPICS class and then returned shortly thereafter. Approximately two weeks later, the programming students delivered a presentation of the salient features of their resultant application to both their classmates and the EPICS students, which was evaluated using one of the rubrics. The application and final documentation were also evaluated using similar rubrics. For the Spring 2015 term project, these rubrics were replaced with rubrics using the "single point" format [22] that were developed in the special topics course. A single point rubric outlines for each criterion what constitutes appropriate performance at the *Proficiency* level; however, the remaining cells under the *Mastery*, *Developing*, and *Lacking* performance levels are intentionally left blank. Unlike the traditional rubric format where all performance levels have specified traits, the single point rubric is designed to naturally encourage both constructive criticism and, when merited, praise through providing written feedback in the relevant blank area whenever the observed performance level (or traits) for a given criterion is either above or below *Proficiency* [22].

Another change was to increase the entrepreneurial nature of the project by replacing the typical "death by PowerPoint" presentations with an interactive science fair style format where judges interacted one-on-one with each team. Each team was expected to have an elevator pitch, a display featuring a value proposition extolling the benefits of adopting their application, and provide a live demonstration. However, as the judges included faculty from Ohio Northern University's Education Department, laboratory assistants comprised of computer science and computer engineering upperclassmen, and the STEM Outreach coordinator for the College of Engineering, teams had to appropriately tailor their presentation to the different audiences. Accordingly, the judging rubric assessed the entrepreneurial aspects of the project and its presentation, such as overall appeal, degree of innovation, intuitiveness, and value qualification. The client evaluation rubric focused on the usability of the application as an educational tool and the degree to which the teams collaborated with their client, including the timeliness of when deliverables were sent. Finally, a single point rubric adapted from the AAC&U Teamwork VALUE Rubric was utilized for peer evaluation [23] and an accompanying heuristic was used in conjunction with scores from other rubrics to determine individual and team contributions.

PROJECT OVERVIEW AND DISCUSSION

The 24 students enrolled in the Spring 2015 offering of Programming 2 were divided into eight teams of three students each, with two students from the special topics course serving as clients. Three lesson plans were written concerning digital logic, electric circuits, and kinetic energy, which were all distributed to the teams. After a bidding process, each team was assigned one of the three lesson plans; therefore, multiple teams had the same lesson plan, thereby introducing a sense of competition which was reinforced by offering the team receiving the highest overall score from the judges a cash award.

Once the teams received their lesson plan and client assignment, the collaboration began with the special topics students visiting the programming class and meeting with their teams. Once they had decided on a feasible concept, each team wrote a short proposal and sent it to their client for approval. The proposal was evaluated using another single point rubric, which provided written feedback for improving their proposed design and, in one case, how to revise their proposal. As the applications were developed, teams periodically provided demonstrations and updates for their client. Leading up to the science fair presentations, collaboration with the clients generally waned as most teams focused on the technical and communicative aspects of the project, such as debugging code and preparing their elevator pitches. The science fair approach worked well as the teams could demonstrate their application and respond to questions as warranted by the discussion with each of the judges. Presenting to these outside audiences enabled the students to receive targeted feedback atypical of the normal programming laboratory experience. Client feedback resulted in two of the eight submitted applications being rejected for classroom use.

Upon initial reflection, the single point rubrics served their function; however, there is room for improvement. Incorporating evaluations for grammar and contextual operational performance needs to be included, as one application was riddled with such errors. Additionally, some of the key elements of the proposal rubric did not transfer over to the final evaluation, such as "concept" and "student engagement." Finally, students would benefit from participation in a norming exercise prior to the actual use of the single point peer evaluation rubric used with this project.

Detailed quantitative assessment was collected using the CSAS instrument as both a pre-activity and post-activity survey, along with open-ended qualitative post-activity questions. Improvements over the previous cohort's performance were noted in nine out of the 10 attitudinal dimensions measured by the instrument. The results from a more detailed analysis of the data are pending.

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AUTHOR INFORMATION

John K. Estell Professor of Electrical & Computer Engineering and Computer Science, Ohio Northern University, j-estell@onu.edu

David Reeping Undergraduate Student in Engineering Education, Ohio Northern University, d-reeping@onu.edu

Heather Sapp Undergraduate Student in Engineering Education, Ohio Northern University, h-sapp@onu.edu

Alexandra Seda Undergraduate Student in Electrical Engineering, Ohio Northern University, a-seda@onu.edu