Employing Project-based Learning to Address the Next Generation Mathematics Standards in High Schools

Afrin Naz, Mingyu Lu, Kenan Hatipoglu
West Virginia University Institute of Technology
Montgomery, West Virginia, USA
afrin.naz@mail.wvu.edu

Karen Rambo-Hernandez
College of Education and Human Services
West Virginia University
Morgantown, West Virginia, USA

***Abstract*—In the summer of 2015, a five-day professional development workshop was held at West Virginia University Institute of Technology, located in Montgomery, West Virginia, with the objective of providing systematic training of project-based learning to high school math teachers. Twenty-two teachers participated in the workshop. Instructors of the workshop were faculty members from West Virginia University Institute of Technology, West Virginia University, and West Virginia State University. The workshop's focus was project-based learning, which employs projects closely related to real-world applications to facilitate delivering abstract concepts. Specifically during the workshop, the participating high school math teachers learned designing engineering projects, mapping engineering projects to Next Generation math standards/objectives, and assessing the outcomes of project-based learning. Each participating teacher is required to implement at least one engineering project in his/her math class and the results will be collected by the superintendents of the three participating school districts. The workshop has two primary hypotheses: (i) teachers who participated in the workshop will increase their self-efficacy toward implementing project-based learning, applying engineering and technology to address content standards and objectives, and using assessments to inform instruction, and (ii) project-based learning will improve students' self-efficacy and learning effectiveness in math, and in turn, will increase their interest/intention to pursue STEM disciplines. The impact of the workshop on teachers is determined through surveys and interviews. Social Cognitive Career Theory is applied to evaluate the impact of project-based learning on the participating teachers' students. Results of the surveys, interviews, and student performance will be presented at the conference.**

Keywords—high school; mathematics education; project-based learning

I. INTRODUCTION

In the summer of 2015, a five-day professional development workshop was held at West Virginia University Institute of Technology, located in Montgomery, West Virginia, with the goal of providing systematic training of project-based learning to high school math teachers. Twenty-one in-service teachers (from Nicholas County Schools, Raleigh County Schools, and Kanawha County Schools of West Virginia) and one pre-service teacher participated in the workshop. Instructors of the workshop were faculty members from West Virginia University Institute of Technology, West Virginia University, and West Virginia State University.

The workshop's focus is project-based learning, which employs projects closely related to real-world applications to facilitate delivering abstract concepts [1]. Project-based learning is well grounded in scientifically-based research and enormous prior research has generated encouraging evidences demonstrating that, project-based learning succeeded in developing students' positive attitudes towards math and science, promoting students' collaboration skills, increasing students' content knowledge, and enabling students to transfer knowledge to practical implementation. For instance according to Frank et al., students found that the project-based format motivated students to learn and made them feel a greater sense of responsibility for their learning [2]. As another example, it was concluded by Schachterle and Vinther that, students were inspired to learn actively through open-ended projects as they appreciate the usefulness of knowledge in textbooks [3]. Moreover when project-based learning is used to supplement instructions, students are inspired to pursue STEM careers [4]. In 2012, the Office of Research of West Virginia Department of Education conducted a research on the effect of project-based learning; its report reveals that, teachers who received extensive training on project-based learning were capable of teaching the 21st Century Standards more effectively compared with teachers without experience on project-based learning [5].

Our workshop followed the project-based learning framework designed by West Virginia Department of Education [6]. Specifically during the workshop, the participating high school math teachers learned designing engineering projects, mapping engineering projects to Next Generation math standards/objectives, and assessing the outcome of project-based learning. Each participating teacher is required to implement at least one engineering project in his/her math class. In the Fall semester of 2015, we had follow-up meetings with the participating teachers, and the teachers presented their plan to implement project-based learning in their classrooms. In the Spring semester of 2016, we will have another round of follow-up meetings with the teachers, and the teachers are expected to present the outcomes of their

This work is sponsored by West Virginia Higher Education Policy Commission, Kanawha County Schools, Raleigh County Schools, and Nicholas County Schools.

implementation of project-based learning. By the end of Spring semester of 2016, the projects delivered in high school classes will be collected by the superintendents of the three participating school districts. The workshop has two primary hypotheses: (i) teachers who participated in the workshop will increase their self-efficacy toward implementing project-based learning, applying engineering and technology to address content standards and objectives, and using assessments to inform instruction, and (ii) project-based learning will improve students' self-efficacy and learning effectiveness in math, and in turn, will increase their interest/intention to pursue STEM disciplines. The impact of the workshop on teachers is determined through surveys and interviews. Social Cognitive Career Theory [7] is applied to evaluate the impact of project-based learning on the participating teachers' students. Survey results collected after the workshop indicate that teachers felt more confident in incorporating project-based learning into their teaching. Results of other surveys, interviews, and student performance will be presented at the conference.

II. Implementation of Workshop

The five-day workshop was held on the campus of West Virginia University Institute of Technology, located in Montgomery, West Virginia, in July 2015. The participants included 21 in-service high school math teachers (from Nicholas County Schools, Raleigh County Schools, and Kanawha County Schools of West Virginia) and 1 pre-service teacher. Instructors of the workshop were from three institutions of higher education, West Virginia University Institute of Technology, West Virginia University, and West Virginia State University. Agenda of the five-day workshop is shown in Table I.

The workshop focused on mentoring high school teachers to apply project-based learning in their math courses. On the first day of the workshop, fundamental principles of project-based learning were instructed to the participating high school teachers. To be specific, teachers learned how to design, develop, and deliver project-based learning in theory. On Day 1 and Day 2, several sample projects were demonstrated to the teachers. The sample projects were classified into three categories: computer graphics, electrical engineering, and mechanical engineering. Computer graphics projects were based on Google SketchUp software [8]; as shown in Fig. 1(a), teachers were using Google SketchUp to create graphics. Electrical engineering projects were based on Snap Circuits Hardware Kits [9]; the photo in Fig. 1(b) was taken when teachers were building circuits. Mechanical engineering projects were based on Gear and Lever Kit [10]; in the photo of Fig. 1(c), teachers were learning various mechanical concepts such as rotary motion, torque, and gear ratio using the kit. All the sample projects require inexpensive parts/components, so that they could be readily applied in high school classrooms. Meanwhile, all of them are designed to address certain West Virginia Next Generation content standards and objectives [11] in the 9th grade or 10th grade math. The morning sessions of Day 3 were dedicated to mapping engineering projects to math standards and objectives. In the assessment sessions on Day 4, the participating teachers learned how to develop effective assessment tools to evaluate the impact of project-based learning. The teachers were divided into groups on Day 3, with three or four teachers from the same school district in each group. Each group selected a target standard/objective and then developed a project to address the target standard/objective, following the protocol established by West Virginia Department of Education [6] and mentored by university faculty members. On Day 5, each project developed during the workshop was presented and discussed. Each group also received comprehensive comments from university faculty members. Fig. 1(d) shows a group of teachers presenting their project on the last day of the workshop.

In addition to project-based learning, the workshop included a few special sessions important for the participating high school teachers. In the "cutting edge sessions" on Day 1 and Day 3, university faculty members presented multiple cutting edge science and technologies such as Cloud Computing, Internet of Things, Connected Vehicles, and renewable energy harvesting, with live demonstrations from ongoing research projects. The major discussion topic of "networking session" on Day 2 was transition from K-12 study to college study; in this session, high school teachers and university educators shared their teaching experiences. In the "diversity session" on Day 3, high school teachers interacted with experts from West Virginia State University on initiatives to recruit traditionally underrepresented groups in STEM fields, namely women and minorities. Two training sessions were offered on Day 4: one was on general assessment tools (that is, not specifically for project-based learning), and the other one was on Google software tools for online instruction.

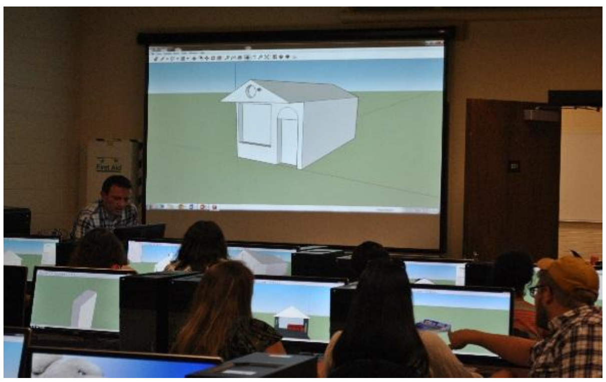
After the workshop, each participating high school teacher is expected to adapt at least one engineering project he/she learned/developed at the workshop to his/her classroom. $500 budget was allocated for each teacher to develop and implement projects after the workshop. For each project delivered in high school classrooms, high school teachers are expected to develop effective assessment instruments to evaluate its impact to address certain Next Generation math standards/objectives. Both online and on-site supports were offered by university faculty members and university students after the workshop. In the Fall semester of 2015, organizers and participants of the summer workshop attended a range of one-day follow-up meetings, and the teachers presented their plan to implement project-based learning in their classrooms. Another round of follow-up meetings are scheduled in the Spring semester of 2016, and the teachers are expected to present the outcomes of their implementation of project-based learning. By the end of Spring semester of 2016, the projects delivered in high school classes will be collected by the superintendents of the three participating school districts.

III. Results

The workshop has two primary hypotheses: (i) teachers who participated in the workshop will increase their self-efficacy toward implementing project-based learning, applying engineering and technology to address content standards and objectives, and using assessments to inform instruction, and (ii) project-based learning will improve students' self-efficacy and learning effectiveness in math, and in turn, will increase their interest/intention to pursue STEM disciplines. The impact of

Table I. Agenda of summer workshop

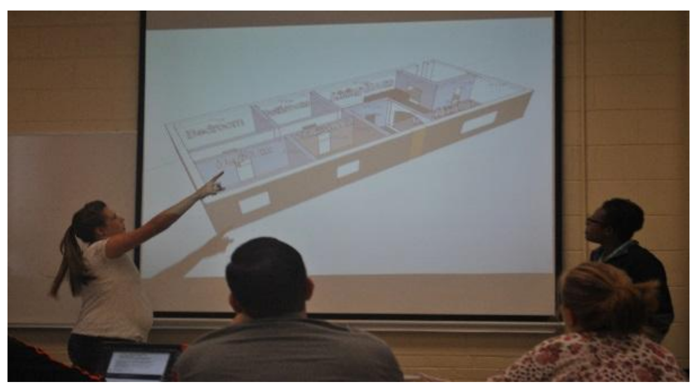
	9 – 10 AM	10 AM – 12 PM	12 – 1 PM	1 – 3 PM	3 – 4 PM	4 – 5 PM
Monday July 6	Inaugural session	Theoretical session: Project-based learning	Lunch	Computer graphics session		Cutting edge session
Tuesday July 7	Electrical engineering session		Lunch	Mechanical engineering session		Networking session
Wednesday July 8	Theoretical session: Mapping to Next Generation math standards		Lunch	Project development	Cutting edge session	Diversity session
Thursday July 9	Theoretical session: Assessments		Lunch	Group work on assessment	Training session: Online instruction tools	
Friday July 10	Project presentations		Lunch	Concluding session: Surveys and follow-up plan		



(a) Participating teachers learning computer graphics projects

(b) Participating teachers learning electrical engineering projects

(b) Participating teachers learning mechanical engineering projects



(d) A group of teachers presenting a project they developed

Fig. 1. Four photos taken at the summer workshop.

the workshop on teachers is determined through surveys and interviews. Social Cognitive Career Theory is applied to evaluate the impact of project-based learning on the participating teachers' students. At present, we are still in the process of collecting results from students and have not collected the final survey data from the participating teachers. Survey results collected during and after the workshop from the teachers are presented in this section. Results of the

Table II. Results of paired sample *t*-test for context specific self-efficacy at pretest and posttest

	n	Pretest mean (SD)	Posttest mean (SD)	*t*	*p*	*d*
Project-based learning self-efficacy	20	3.03 (0.82)	3.85 (0.78)	4.34	<.001	1.02
Use of technology in the classroom self-efficacy	20	3.23 (0.86)	3.98 (0.75)	5.25	<.001	0.93
Incorporating engineering self-efficacy	20	2.23 (0.95)	3.48 (0.97)	5.41	<.001	1.30
Use of assessment self-efficacy	20	3.28 (0.82)	3.94 (0.6)	4.42	<.001	0.92

outstanding student and teacher surveys, interviews, and student performance will be presented at the conference.

Overall, surveys collected after the workshop indicate that, the workshop succeeded in instructing the basic concepts of project-based learning to the participating teachers and increasing their confidence of incorporating project-based learning into their teaching. For instance in a survey question after the workshop, the participating teachers were asked "did the workshop increase your knowledge and skills relative to the topic presented?"; out of the 22 teachers who completed the survey, 20 answered "very well" (highest scale), 2 answered "moderately" (second highest scale), and none answered "somewhat" or "not at all."

Participating teachers ($n = 22$) took an online survey before participating in the workshop (pretest) and on the last day of the workshop (posttest). The online survey assessed teacher self-efficacy in four areas: incorporating project-based learning into the classroom, using technology in the classroom, integrating engineering into the classroom, and using assessments effectively in the classroom. Twenty teachers participated at both pretest and posttest.

For all scales, teachers responded on a scale from 1 (no confidence at all) to 5 (complete confidence) to questions about their self-efficacy in the specific areas. The self-efficacy scale for incorporating project-based learning contained three items such as "How much confidence do you have in your ability to write lesson plans that incorporate project-based learning?" The self-efficacy scale for using technology in the classroom contained three items such as "How much confidence do you have in your ability to use technology to improve student learning?" The self-efficacy scale for integrating engineering into the classroom contained two items such as "How much confidence do you have in your ability to incorporate mechanical engineering content into my instruction?" The final self-efficacy scale for using assessments in the classroom contained five items such as "How much confidence do you have in your ability to create assessments that accurately measure student learning?" All scales demonstrated high reliability ($r > .90$).

Because we assessed the same teachers on multiple scales ($n = 4$), we applied a Bonferroni correction before conducting paired sample *t*-tests to lessen the chance of making a type-1 error and set the significance level a-priori at $p < .0125$. Results of the paired sample *t*-tests are provided in Table II. Results indicated that teachers had statistically higher self-efficacy in each of the four areas assessed at posttest when compared to pretest. Further, the effect sizes for all paired sample *t*-tests were large ($d > .80$).

IV. Conclusions

While the data are still being collected, the initial results indicate the teachers did increase their self-efficacy toward incorporating project-based learning, integrating engineering and technology with their teaching, and using assessments. At the time of submission, teachers were still actively using skills learned at the workshop, thus we have not collected the final data from students, conducted teacher interviews, or had the teachers respond to a final survey. We are anxious to see how the increases in teacher self-efficacy translate to student self-efficacy, outcome expectations, interest in STEM, and academic performance as defined by Social Cognitive Career Theory.

The Next Generation math standards include Mathematical Practices Standards, which require integrating engineering practice with math teaching. Many math teachers may not have adequate training in engineering, and this study illustrates that a well-designed one-week workshop may be able to begin to fill the void of knowledge and application of engineering concepts in math education.

There are limitations to the study, which may limit the generalizability of the results. Primarily, this study did not have a control group for the teachers or students. The change in self-efficacy likely occurred due to the implementation of the workshop but we cannot be certain without a true experimental design. Further, we do not know what aspects of the workshops were the catalyst to these changes.

REFERENCES

[1] J. W. Thomas, A Review of Research on Project-Based Learning. San Rafael, CA: Autodesk Foundation, 2000.

[2] M. Frank, I. Lavy, and D. Elata, "Implementing the project-based learning approach in an academic engineering course," International Journal of Technology and Design Education, vol. 13, no. 3, pp. 273–288, 2003.

[3] L. Schachterle and O. Vinther, "Introduction: The role of projects in engineering education," European Journal of Engineering Education, vol. 21, no. 2, pp. 115–120, 1996.

[4] R. A. Atadero, K. E. Rambo-Hernandez, and M. M. Balgopal, "Using social cognitive career theory to assess student outcomes of group design projects in statics," Journal of Engineering Education, vol. 104, no. 1, pp. 55–73, 2014.

[5] N. K. Hixson, J. Ravitz, and A. Whisman, "Extended professional development in project-based learning: Impacts on 21st century skills teaching and student achievement," West Virginia Department of Education, September 2012.

[6] http://wvde.state.wv.us/teach21/PBLTools.html

[7] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a unifying social cognitive theory of career and academic interest, choice, and performance," Journal of Vocational Behavior, vol. 45, no. 1, pp. 79–122, 1994.

[8] http://www.sketchup.com/

[9] http://www.scientificsonline.com/shop/science-kits/electric-kits

[10] https://www.sciencelabsupplies.com

[11] https://wvde.state.wv.us/teach21/NxGCSOs.html