

## **Improving High School Math Teachers' Confidence and Skills in Assessment of Engineering Project-Based Learning**

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National Science Foundation reports continue to indicate low participation in science, technology, engineering, and mathematics (STEM) education and STEM careers, especially among minorities and women (National Science Board, 2016; Thomasian, 2011). A change in current classroom practices is needed if schools are going to attract more students to STEM fields. More hands-on, real-life problem solving can help generate excitement among students and has the potential to attract more students to STEM (Christensen, Knezek, & Tyler-Wood, 2015). One way to provide more meaningful problem solving activities is problem-based learning in science, technology, engineering, and mathematics. Engineering PBL can bring the four content areas together in a way that is meaningful to students. Tamim and Grant (2013) found teachers may have a difficult time implementing new instructional strategies like PBL. Many teachers lack the training necessary to confidently implement PBL in their classrooms and to assess student learning as a result of PBL. Teacher training directed at improving teachers' confidence and skills in implementing and assessing engineering PBL is needed.

Efforts have been made to improve STEM instruction in the K-12 education system. Recently, states have come together to develop a common set of mathematics and science standards to standardize, at a national level, what students should know and be able to do. Carr, Bennett, and Strobel (2012) found that 41 of the 50 states represent engineering standards in their state K-12 mathematics and science academic standards. However, adding new standards without adding supports for teachers to effectively incorporate the engineering standards is unlikely to attract more students STEM.

Innovative teaching methods that provide real-life experiences can help students see application beyond the classroom and can generate more interest in STEM careers. The Framework for K-12 Science Education (National Research Council, 2012) explained science as “not just a body of knowledge but also a set of practices for investigating, modeling, and explaining phenomena in the natural world” (Harris et al., 2015). Included in the new national science standards were science and engineering practices. Engineering design is a way to address these practices. Engineering design is the process of formulating a problem that describes a real-world scenario and designing a solution to the problem (NRC, 2012). While engineering design is not specifically addressed in the “*Principles and Standards for School Mathematics*” developed by the National Council of Teachers of Mathematics (NCTM, 2000), “essential elements of mathematical problem solving needed to support engineering design are described in several of the standards” (Householder & Hailey, 2012). Solutions to these real-world scenarios may involve a variety of tasks that require mathematical skills such as expressing relationships and analyzing data. Science, technology, engineering, and mathematics courses should not be taught in isolation. Educators must be able to incorporate all four fields into every mathematics and science course.

Engineering design has the potential to attract more students to STEM because it involves active learning. Active, hands-on learning helps engage students in activities that relate to the real world. Christensen, Knezek, and Tyler-Wood (2015) found involving students in active learning “may be effective in promoting (or retaining) positive interest in STEM content and careers.”

When students are engaged in meaningful tasks that incorporate facets of science, technology, engineering, and mathematics, they will develop a stronger self-concept and greater interest in STEM fields. Engineering design activities increase students' interest and self-efficacy in engineering and their problem-solving abilities (Householder & Hailey, 2012). Thomasian (2011) noted when students were not provided with opportunities to engage in hands-on STEM activities, their ability to complete a postsecondary degree in a STEM field was diminished. He also stated that without a "rich supply of STEM-skilled individuals" the United States would struggle "to compete in the global economy, where discovery, innovation, and rapid adaptation are necessary elements for success." One way teachers can increase interest in STEM fields and improve student learning is by incorporating engineering project-based learning (PBL) units into high school mathematics classrooms.

Project-based learning (PBL) provides an opportunity for students to learn concepts by designing solutions to scenarios that are close to those found in real life. Since engineering applies science knowledge to designing solutions to real-world problems, PBL provides an avenue for students to learn engineering skills in math and science courses. Studies have shown the use of PBL improves students' learning and improves students' beliefs in their abilities to complete complex tasks in engineering (Householder & Hailey, 2012). PBL has been shown to improve students' attitudes toward learning, team communication, collaboration skills, and creativity as well as students' academic achievement in mathematics (Han, Capraro, R. & Capraro, 2015; Householder & Hailey, 2012; Tamim & Grant, 2013). PBL has also been shown to develop problem-solving and system thinking skills (Householder & Hailey, 2012). Finally, PBL allows teachers to differentiate instruction to accommodate individual students' needs (Tamim & Grant, 2013).

To effectively implement PBL in the classroom, teachers must be adequately trained. In some cases, teachers may have a difficult time implementing new instructional strategies (Tamim & Grant, 2013). Teachers need to have the skills to develop the projects, to facilitate students' efforts, and to assess students' learning. Many teachers lack the skills to design effective assessments of PBL (Marxm Blumenfeld, Krajcik, & Soloway, 1997; Tamim & Grant, 2013), so the benefits of PBL often go unnoticed.

Prior to assigning a project, teachers need to assess students' prior knowledge. The teachers then need to know how to use data from the assessments to inform instruction. Householder and Hailey (2012) observed that teachers frequently use pretest, posttest assessment designs to assess students' understandings in different engineering activities which can include PBL. Once students complete the project, teachers must assess student learning to ensure the intended learning objectives have been met. Professional development, such as the workshop conducted for this study, supports teachers "as they change from information-transmission models to those that stress students' transformation of ideas" (Marx et al., 1997).

Many researchers have examined how to design effective assessments. Jideani and Jideani (2012) explained how to implement assessments that align with instructional objectives. Kulm, Wilson, and Kitchen (2005) discussed what to look for in effective assessment of mathematics content. Sandin, Harshman, and Yeziarski (2015) examined chemistry assessment items looking specifically at the items' features, such as specific versus ambiguous goals and single versus

multiple concepts assessed in a single item. Several researchers studied the alignment of curriculum, assessment, and instruction at the state level (Martone & Sireci, 2009; Roach, Niebling, & Kurz, 2008; Newton & Kasten, 2013). These studies highlight different methods for evaluating alignment with state-wide assessments; however, these methods can be adapted for use by teachers in evaluating assessments for classroom use. For our purposes, we chose to use classical test theory (Novick, 1966) as a framework for creating assessments of PBL.

## The Current Study

This study was designed to improve teachers' competence in assessing PBL by teaching teachers how to create assessment blueprints based in classical test theory (Novick, 1966) and how to use the data from the assessments to measure mastery of the PBL content objectives. Teachers participated in a five-day project-based learning workshop. The workshop prepared teachers to plan, implement, and assess engineering PBL in their high school mathematics courses. Teachers had the opportunity to sample projects they could take back to their own classrooms. Teachers also mapped engineering projects to their state standards and worked in groups to develop their own projects. Finally, teachers learned to develop effective assessment tools. Data on teachers' confidence in the use of technology, confidence in engineering content, confidence in implementing PBL in their classrooms, and conceptions of assessment was collected and analyzed. Researchers examined the blueprints and assessments created by the teachers. And during the school year following the workshop, teachers implemented engineering PBL and used the assessments they created to measure students' learning. The impact of the workshop on improving high school math teachers' confidence and skills in implementing and assessing engineering PBL is reported.

## Methods

Twenty-one in-service high school mathematics teachers from three different counties and one pre-service teacher participated in a five-day professional development workshop. The goal of the workshop was to provide systematic training of PBL to high school mathematics teachers. Teachers had the opportunity to engage with multiple engineering concepts, develop projects to take back to their classrooms, and create assessments to determine what students learned through engineering-based PBL.

Teachers participated in a five-day project-based learning workshop conducted by instructors from three institutions of higher education. The workshop focused on mentoring high school teachers in preparation for them to apply project-based learning in their math courses during the following school year. On the first day of the workshop, teachers learned how to design, develop, and deliver PBL. During the first two days, sample projects in computer graphics, electrical engineering, and mechanical engineering that could be readily applied in high school classrooms were demonstrated to the teachers. On the third day, teachers mapped engineering projects to mathematics standards and objectives and worked in groups to develop a project to address selected standards and objectives. On the fourth day, participating teachers learned how to develop effective assessment tools to evaluate the outcome of project-based learning. On the last day, the projects were presented and discussed with each group receiving feedback from the

instructors. After attending the workshop, thirteen teachers reported on the implementation of their engineering projects in their high school mathematics classrooms.

*Confidence in technology and engineering content.* Prior to participating in the PBL workshop, teachers were asked to complete a survey indicating confidence in their ability to use modern technologies to enhance student achievement. Teachers were asked to rate their confidence in using technology to enhance instruction and in using technology to improve student learning on a scale of 1-5 with 1 indicating no confidence and 5 indicating complete confidence. The teachers were also asked to rate their confidence in incorporating computer science, electrical engineering, and mechanical engineering contents into their mathematics classrooms on the same scale of 1-5. After participating in the workshop, the teachers were asked to again rate the same statements.

*Confidence in implementing and assessing project-based learning.* The survey given to teachers prior to participation in the workshop and after participation in the workshop also asked teachers to rate their confidence in implementing project-based learning in their classrooms. The three items asked teachers to rate their confidence in their ability to “incorporate project-based learning into at least one instructional unit,” “write lesson plans that incorporate project-based learning,” and “use project-based learning within my existing curriculum (instead of in addition to my curriculum)” on a scale of 1-5. Teachers were also asked to rate their confidence in assessing project based learning on the same scale of 1-5 for five statements. Examples of items include rating their confidence to “measure student learning against specific objectives,” “create assessments that accurately measure student learning,” and “create assessments that provide students useful information about their learning.” A reliability analysis was conducted for each subscale to identify potentially problematic items. Based on coefficient alphas, the confidence in incorporating PBL ( $\alpha = .94$ ) and confidence in assessing student learning through PBL ( $\alpha = .93$ ) scales had acceptable estimated reliability for the teachers.

*Conceptions of assessment.* The survey given to teachers prior to participation in the workshop and upon completion of the workshop included statements from the Teacher Conceptions of Assessment (Brown, 2004). Teachers were given twenty-seven statements and were asked to rate how much they agreed with each statement about assessment on a 5-point scale with 1 indicating strongly disagree and 5 indicating strongly agree. The items fell into six categories: assessment makes schools accountable, assessment describes student learning, assessment improves student learning, assessment improves the quality of learning assessment provides valid information, and assessment is bad for students and teachers. Examples of items for from Brown’s Teacher Conceptions of Assessment include “Assessment is an accurate indicator of a school's quality,” “Assessment is a way to determine how much students have learned from teaching,” “Assessment provides feedback to students about their performance,” and “Assessment allows different students to get different instruction.”

A reliability analysis was conducted for each subscale to identify potentially problematic items. Based on coefficient alphas, the assessment makes schools accountable ( $\alpha = .88$ ), assessment describes student learning ( $\alpha = .70$ ), assessment improves student learning ( $\alpha = .85$ ), assessment improves the quality of teaching ( $\alpha = .75$ ), assessment provides valid information ( $\alpha = .86$ ), and

assessment is bad for students and teachers ( $\alpha = .89$ ) scales had acceptable estimated reliability for the teachers.

*Blueprints and teacher-made assessments.* Teachers created assessments to evaluate the mathematical concepts incorporated through engineering-based PBL. The teachers received instruction in the development of assessments to evaluate student learning that aligns with targeted standards and objectives. Researchers evaluated alignment between blueprints and pre/post assessments created by teachers to assess the mathematical concepts incorporated through engineering-based PBL.

*Student achievement.* Thirteen teachers reported their incorporation of engineering PBL in their high school mathematics classrooms. The teachers used the assessments they designed to collect data on student performance prior to and after participation the engineering PBL activity.

## Analysis

*Confidence in technology and engineering content.* Teachers completed a self-assessment of their confidence in the use of modern technologies to enhance student achievement and their confidence in incorporating computer science, electrical engineering, and mechanical engineering contents into their mathematics classrooms both before participation in the project-based learning professional development workshop and again after their participation. Paired-samples *t*-tests were conducted to compare teachers' self-assessments of their confidence before and after the workshop. The results were used to determine whether the workshop had an effect on teachers' confidence in the use of modern technologies to enhance instruction and whether the workshop had an effect on teachers' confidence in incorporating computer science, electrical engineering, and mechanical engineering contents into their mathematics classrooms.

*Confidence in implementing and assessing project-based learning.* Teachers completed self-assessments of their confidence in incorporating problem-based learning and their confidence in creating assessments of student learning through project-based learning. Teachers completed the survey before participation in the project-based learning professional development workshop and again after their participation. Paired-samples *t*-tests were conducted to compare teachers' self-assessments of their confidence in incorporating PBL and in creating assessments.

*Conceptions of assessment.* Teachers attending the workshop were also asked to rate their conceptions of assessment using Teacher Conceptions of Assessment (Brown, 2004). The items in these subscales measured different, but important, aspects of their respective factors: assessment makes schools accountable, assessment describes student learning, assessment improves student learning, assessment improves the quality of learning, assessment provides valid information, and assessment is bad for students and teachers. A paired-samples *t*-test was conducted to compare teachers' conceptions of assessment prior to the summer workshop and after participation in the summer workshop.

*Blueprints and teacher-made assessments.* Participating teachers created blueprints and pre/post assessments of their engineering project-based learning units. The teachers submitted the blueprints they used to create the pre/post assessments. Researchers examined each of the

blueprints and assessments to determine the percent of the assessments aligned to the state standards. Success was determined by at least 90% of the assessment directly aligning to the state standard.

*Student achievement.* The thirteen teachers who reported their incorporation of engineering-based PBL into their high school mathematics classrooms used their assessments to evaluate their students before and after the PBL activities. Mean scores were created for each teacher's pretest and posttest scores to measure the difference in each teacher's mean scores from pretest to posttest.

## Results

*Confidence in technology and engineering content.* As part of an engineering problem-based learning workshop, teachers completed self-assessments of their confidence in the use of modern technologies to enhance student achievement. Teachers were asked to indicate their confidence on a scale of 1-5 where 1 indicated no confidence and 5 indicated complete confidence. Teachers completed the survey before participation in the project-based learning professional development workshop ( $N = 23$ ) and again after their participation ( $N = 18$ ). A paired-samples  $t$ -test was conducted on data from teachers who took both the pre-survey and post-survey ( $n = 16$ ) to compare teachers' self-assessments of their confidence in the use of modern technologies to enhance student achievement before and after the workshop. There was a statistically significant difference in the teachers' confidence in their ability to use technology to enhance instruction and the teachers' confidence in the use of technology to improve student learning before and after the workshop (Table 1).

Teachers were also asked to rate their confidence in incorporating computer science, electrical engineering, and mechanical engineering contents into their mathematics classrooms on the same scale of 1-5. There was a statistically significant difference in the teachers' confidences in incorporating computer graphics content, electrical engineering content, electrical engineering content, and mechanical engineering content into their mathematics classroom before and after the workshop. These results suggest the summer workshop did have an effect on teachers' confidence in the use of modern technologies to enhance instruction and their confidence in incorporating engineering concepts in their classrooms. Specifically, the results suggest when teachers receive professional development in the use of modern technology to enhance instruction, their level of confidence in their abilities increases.

*Confidence in implementing and assessing project-based learning.* Teachers were asked to rate their confidence in incorporating engineering PBL and in assessing student learning through PBL. Teachers were asked to indicate their confidence on a scale of 1-5 where 1 indicated no confidence and 5 indicated complete confidence. Teachers completed a survey before participation in the engineering project-based learning professional development workshop ( $N = 23$ ) and again after their participation ( $N = 18$ ). A paired-samples  $t$ -test was conducted on data from teachers who took both the pre-survey and post-survey ( $n = 16$ ). There was a statistically significant difference in the teachers' confidence in incorporating PBL and in teachers' confidence in assessing PBL before and after participation in the workshop (Table 2).

*Conceptions of assessment.* Teachers attending the PBL workshop were given twenty-seven statements from the Teacher Conceptions of Assessment (Brown, 2004). They were asked to rate how much they agreed with each statement about assessment on a 5-point scales with 1 indicating strongly disagree and 5 indicating strongly agree. A paired-samples *t*-test was conducted to compare teachers' conceptions of assessment prior to the summer workshop and after completing the workshop. There was a statistically significant difference in the teachers' agreement that assessment describes student learning, improves the quality of learning, and is bad for students (Table 3). There was not a statistically significant difference in the teachers' agreement that assessment makes schools accountable, improves student learning, or provides valid information.

*Blueprints and teacher-made assessments.* Teachers submitted the blueprints they used to create the pre/post assessments. Each of the blueprints and assessments were examined to determine the percent of the assessments aligned to the state standards. Success was determined by at least 90% of the assessment directly aligning to the state standard. Of the teachers who submitted their blueprints and assessments, 100% of every assessment was aligned to the state standards.

*Student achievement.* The thirteen teachers who reported on their incorporation of engineering-based PBL into their high school mathematics classrooms used their assessments to evaluate their students before and after the activities. All of the teachers noted an improvement in the students' assessment scores when comparing the pretest ( $M = 32.6$ ,  $SD = 28.2$ ) to the posttest scores ( $M = 65.0$ ,  $SD = 29.5$ ). Nine of the teachers saw a statistically significant increase in students' performance on the posttest as compared to the pretest (Table 4). The statistically significant increase indicates an increase in student achievement after participating in engineering based PBL. Figure 1 displays these results graphically. In summary, student achievement increased with the incorporation of PBL in their mathematics classrooms.

## Discussion

Teachers are well positioned to encourage students' engagement in STEM education and STEM careers. High school mathematics teachers can increase participation in STEM by incorporating engineering problem-based learning in their classrooms. In order to effectively implement and assess engineering PBL, teachers need additional support. Workshops, such as the five-day project-based learning workshop utilized for this study, can provide teachers with the confidence and skills necessary to implement PBL in their classrooms. As a result of participation in this study, the participating high school mathematics teachers developed engineering PBL projects they could use in their own classrooms. They also learned to create their own assessments of student learning through PBL activities. The teachers used the assessment they created during the professional development to assess student learning through the engineering PBL projects they developed during the workshop.

After participation in the workshop, teachers indicated a more positive view of the use of assessments and a greater confidence in their abilities to design effective assessments and implement PBL. The teachers who participated in the workshop were able to develop assessments entirely aligned to the content objectives identified in their blueprints. This study



provided a model for addressing the lack of skills to design effective assessment of PBL (Marx et al., 1997; Tamim & Grant, 2013).

As part of the study, teachers received instruction on designing effective assessments of PBL based in classical test theory (Novick, 1966). These assessments allowed teachers to measure student mastery of the content. When the teachers administered the assessments they designed, most experienced a statistically significant increase in student learning through students' participation in the engineering PBL activities. The results of these assessments supported the claims that PBL leads to greater retention of the concepts being learned (Wirkala & Kuhn, 2011).

While this study provided evidence of teachers' increased confidence in designing assessments for engineering PBL, this study did have limitations. Violations of internal validity limited the inferences that could be made. The sample size was small and was limited to a small community of teachers. The teachers self-selected to participate in the study, and teachers who chose to participate in this workshop may have had characteristics leading to an overstatement of the impact of the workshop. Additionally, exposure to the pre-assessment may have influenced students' scores on the post assessment.

To better understand the impact of training in engineering problem-based learning, additional workshops can be designed to reach a larger number of participants. Randomly selecting participants for these workshops will address the selection threat to internal validity and will allow researchers to determine if the workshop is the cause of the increase in confidence and positive conceptions of assessment.

This study was designed to improve teachers' confidence and skills in implementing engineering PBL. Student mastery of content was assessed as further evidence of the impact of the teachers' classroom implementation; however, the impact of the engineer PBL on students was not assessed. The desired outcome of implementing engineering PBL in the high school mathematics classroom is to increase student interest in STEM education. Further studies to determine if the use of engineering PBL in the mathematics classroom is effective would be beneficial.

## Conclusions

The findings of this study were supported by the literature and indicated teachers would benefit from professional development designed to teach teachers how to effectively implement and evaluate engineering PBL in high school mathematics classrooms. Continued efforts to assist teachers in developing the skills needed to assess engineering PBL were warranted. Marx et al. (1997) asserted that supporting teachers as they begin to move toward models that help students apply their learning in innovative ways would help promote future implementation of PBL in the classroom. Supporting teachers through professional development can increase the probability teachers will implement new instructional designs that will increase the number of students entering STEM fields.

## References

- Brown, G. T. (2004). Teachers' conceptions of assessment: Implications for policy and professional development. *Assessment in Education: Principles, Policy & Practice*, 11, 301-318. doi: 10.1080/0969594042000304609
- Carr, R. L., Bennett, L. D. IV, & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education*, 101(3), 539-564. doi: 10.1109/TAES.1980.308907
- Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology*, 24(6), 898-909. doi: 10.1007/s10956-015-9572-6
- Han, S., Capraro, R., & Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, 13, 1089-1113. doi: 10.1007/s10763-014-9526-0
- Harris, C.J., Penuel, W.R., D'Angelo, C.M., DeBarger, A.H., Gallagher, L.P., Kennedy, C.A., &...Krajcik, J.S. (2015). Impact of project-based curriculum materials on student learning in science: Results of a randomized controlled trial. *Journal of Research in Science Teaching*, 52(10), 1362-1385. doi: 10.1002/tea.21263
- Householder, D. L., & Hailey, C. E. (Eds.). (2012). *Incorporating engineering design challenges into STEM courses*. Retrieved from <http://ncete.org/flash/pdfs/NCETECaucusReport.pdf>.
- Jideani, V. A. & Jideani, I. A. (2012). Alignment of assessment objectives with instructional objectives using revised bloom's taxonomy – The case for food science and technology education. *Journal of Food Science Education*, 11(3), 34-42. doi: 10.1111/j.1541-4329.2012.00141.x
- Kulm, G., Wilson, L. D., & Kitchen, R. (2005). Alignment of content and effectiveness of mathematics assessment items. *Educational Assessment*, 10(4), 333-356. doi: 10.1207/s15326977ea1004\_2
- Martone, A. & Sireci, S. G. (2009). Evaluating alignment between curriculum, assessment, and instruction. *Review of Educational Research*, 79(4), 1332-131. doi: 10.3102/0034654309341375
- Marx, R.W, Blumenfeld, P.C., Krajcik, J.S., & Soloway, E. (1997). Enacting Project-Based Science. *The Elementary School Journal*, 97(4), 341-358. doi: 10.1086/461870
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council for Teachers of Mathematics.
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards, Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academies Press.
- National Science Board. 2016. Science and Engineering Indicators 2016. Arlington, VA: National Science Foundation (NSB-2016-1).
- Newton, J. A. & Kasten, S. E. (2013). Two models for evaluating alignment of state standards and assessments: Competing or complementary perspectives? *Journal of Research in Mathematics Education*, 44(3), 550-581. doi: 10.5951/jresmetheduc.44.3.fm
- Novick, M. R. (1966). The axioms and principal results of classical test theory. *Journal of Mathematical Psychology*. 3(1), 1-18. doi: 10.1002/j.2333-8504.1965.tb00132.x

Roach, A. T., Niebling, B. C., & Kurz, A. (2008). Evaluating the alignment among curriculum, instruction, and assessments: Implications and applications for research and practice. *Psychology in the Schools, 45*(2), 158-176. doi: 10.1002/pits.20282

Sandin, B., Harshman, J., & Yeziarski, E. (2015). Formative assessment in high school chemistry teaching: Investigating the alignment of teachers' goals with their items. *Journal of Chemical Education, 92*(10), 1619-1625. doi: 10.1021/acs.jchemed.5b00163

Tamim, S.R. & Grant, M.M. (2013). Definitions and uses: Case study of teachers implementing project-based learning. *Interdisciplinary Journal of Problem-based Learning, 7*(2), 71-101. doi: 10.7771/1541-5015.1323

Thomasian, J. (2011). *Building a science, technology, engineering, and math education agenda: An update of state actions*. Washington, DC: National Governors Association Center for Best Practices.

Wirkala, C. and Kuhn, D. (2011). Problem-based learning in k-12 education: Is it effective and how does it achieve its effects? *American Educational Research Journal, 48*(5), 1157-1186. doi: 10.312/002831211419491

Table 1

*Differences Between Teachers' Self-Assessments of Their Confidence in the Use of Technology and Incorporation of Engineering Content Prior to and After Participation in Project-Based Learning Professional Development*

Measure	Pre-Survey		Post-Survey		df	t	p
	M	SD	M	SD			
Use technology to enhance my instruction?	3.50	.82	4.00	.73	15	-3.16	.006*
Use technology to improve student learning?	3.50	.82	3.94	.93	15	-2.41	.029*
Incorporate computer graphics content into my instruction?	2.63	1.15	3.88	.89	15	-5.84	<.001*
Incorporate electrical engineering content into my instruction?	2.25	.93	3.69	1.01	15	-5.97	<.001*
Incorporate mechanical engineering content into my instruction?	2.31	.95	3.63	.89	15	-6.62	<.001*

Note: Only teachers who completed both the pre survey and post survey are included.

\* indicates the difference between teachers' self-assessments prior to and after the workshop was statistically significant

Table 2

*Differences Between Teachers' Self-Efficacy Prior to and After Participation in Project-Based Learning Professional Development*

Measure	Pre-Survey		Post-Survey		df	t	p
	M	SD	M	SD			
Self-efficacy for incorporating PBL	3.06	.84	3.83	.85	15	4.02	<.001*
Assessment self-efficacy	3.19	.89	3.89	.57	15	3.93	<.001*

Note: Only teachers who completed both the pre survey and post survey are included.

\* indicates the difference between teachers' self-assessments prior to and after the workshop was statistically significant

Table 3

*Differences Between Teachers' Conceptions of Assessment Prior to and After Participation in Project-Based Learning Professional Development*

Measure	Pre-Survey		Post-Survey		df	t	p
	M	SD	M	SD			
Assessment makes schools accountable	2.90	.70	2.95	.69	15	-.330	.746
Assessment describes student learning	3.77	.64	4.10	.47	15	-2.15	.048*
Assessment improves student learning	4.02	.58	4.14	.60	15	-1.10	.287
Assessment improves the quality of teaching	3.66	.57	4.03	.46	15	-2.82	.013*
Assessment provides valid information	3.03	.59	3.31	.77	15	-1.59	.132
Assessment is bad for students and teachers	2.27	.65	1.92	.74	15	2.35	.033*

Note: Only teachers who completed both the pre survey and post survey are included.

\* indicates the difference between teachers' self-assessments prior to and after the workshop was statistically significant

Table 4

*Mean Student Test Scores by Teacher Before and After Implementation of Project-Based Learning Activity*

Teacher	Pretest		Posttest		N	<i>t</i>	<i>p</i>
	M	SD	M	SD			
A	61.58	16.75	73.68	21.91	19	3.01	.007*
B	54.62	20.83	60.77	24.97	26	1.27	.215
C	11.00	14.99	88.50	18.61	40	23.51	<.001*
D	4.78	8.09	28.04	27.62	46	5.64	<.001*
E	39.73	12.46	74.20	20.89	41	16.22	<.001*
F	66.52	17.27	72.40	19.49	25	1.21	.238
G	26.67	19.15	54.89	20.43	9	4.73	<.001*
H	51.24	18.90	77.84	15.48	37	9.16	<.001*
I	28.57	16.76	57.14	16.04	7	5.62	<.001*
J	.57	1.61	46.57	32.01	35	8.67	<.001*
K	55.00	12.78	69.33	21.20	3	2.46	.134
L	38.00	12.,75	85.07	12.36	14	31.56	<.001*
M	74.67	10.08	76.67	22.57	15	.44	.668

\*indicates the difference in the mean student scores before and after the objectives were taught is statistically significant

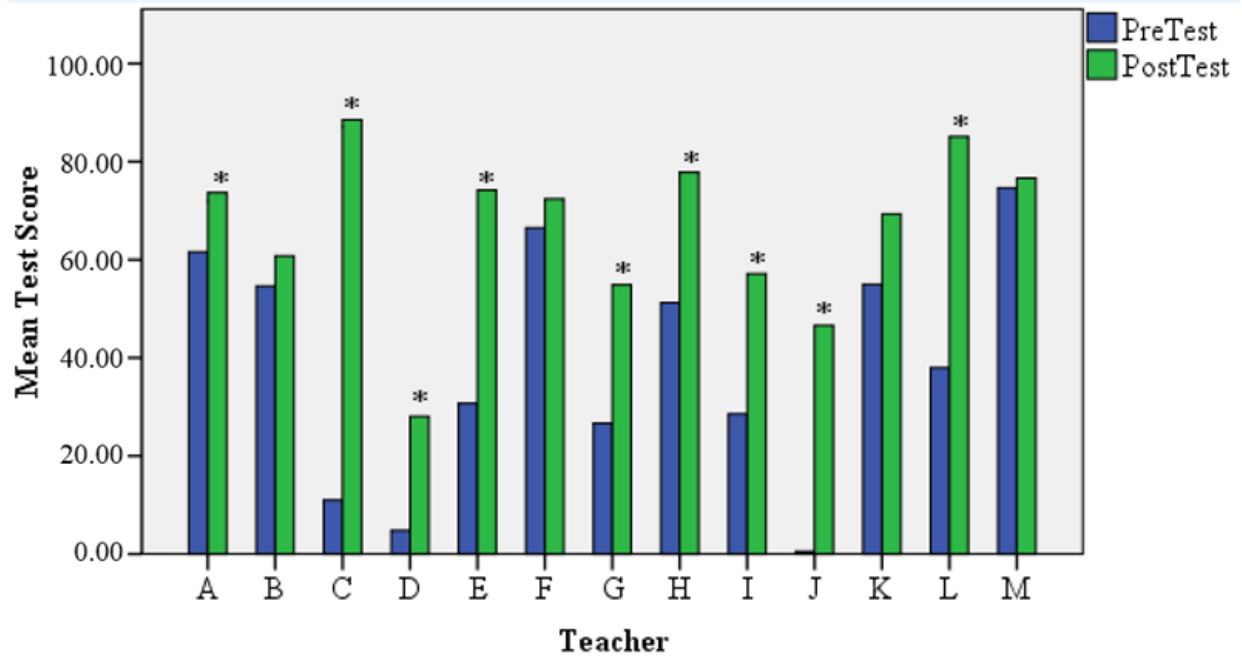


Figure 1: The mean student scores, by teacher, on teacher-created pretests and posttests designed to assess student learning on objectives taught through project-based learning.

\*indicates the difference in the mean student scores before and after the objectives were taught is statistically significant,  $p < .05$