AC 2012-4035: PROBLEM-BASED LEARNING IN A PRE-SERVICE TECHNOLOGY AND ENGINEERING EDUCATION COURSE

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Problem-Based Learning in a Pre-Service Technology and Engineering Education Course

Abstract

Problem-based learning (PBL) is an instructional approach whereby students learn problem-solving, critical thinking and teamwork skills by collaboratively solving complex real-world problems. Research shows that PBL improves student knowledge and retention, motivation, problem-solving skills, and the ability to skillfully apply knowledge in new situations. While used extensively in medical schools since the 1970s. PBL is emerging as an exciting alternative to traditional lecture-based methods in engineering and technology education. One of the challenges for teachers and faculty wishing to adopt PBL strategies in the classroom, however, is the lack of instructional resources and training in pre-service teacher Science, Technology, Engineering, and Mathematics (STEM) education. To address this problem, the STEM-PBL project of the New England Board of Higher Education, funded by the National Science Foundation Advanced Technological Education (NSF-ATE) program, has created a comprehensive series of multimedia PBL "Challenges" focused on sustainable technologies, and training in their use for pre-service and in-service STEM teachers.

In this paper, we present the results of a pilot study conducted to examine the impact of a model PBL methods course based on the STEM PBL Challenges on the knowledge, skills, and attitudes of pre-service K-12 STEM educators with regard to the use of PBL in Technology and Engineering Education (TEE). During the spring 2011 semester, 14 pre-service TEE students enrolled in at Central Connecticut State University participated in the PBL methods course. Qualitative and quantitative methods were used to assess students' motivation, self-efficacy, critical thinking, and metacognitive self-regulation resulting from engagement with the STEM PBL Challenges using selected scales from the Motivated Strategies for Learning Questionnaire (MSLQ). Data were corroborated through focus group interviews with students. While results of pre-post assessments showed overall gains in extrinsic motivation, self-efficacy, critical thinking and metacognitive self-regulation, only critical thinking was statistically significant. Pre-post assessment of content knowledge with regard to PBL methods was also significant.

Introduction

The Bureau of Labor Statistics reports that total employment in science and engineering disciplines will increase by 26% from 2004 to 2014, a rate nearly double the overall growth rate for all other occupations[1,2]. In fact, the long-term growth in the number of positions in science and engineering has far exceeded that of the general workforce, with more than four times the annual growth rate of all occupations since 1980[3]. In spite of such promising job prospects, maintaining enrollment in science and engineering programs has been a real challenge for most colleges and universities nationwide. Unlike their Asian and European counterparts, careers in math and science are not the first choice for the majority of American high school students. According to the report *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, 38% of all South Korean undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure is only 15%[4]. Cleary, if the U.S. is to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter STEM careers must be increased.

One of the reasons for declining enrollment in many STEM programs is that students are often turned off by the way these subjects are taught, with traditional classroom lectures and "cook-book" type laboratory experiences that provide little opportunity to actively engage in creative, real-world problem solving. Engineers and scientists are problem solvers— individuals who skillfully apply their knowledge to tackle real-world problems by designing experiments, building prototypes, analyzing and interpreting data, and presenting experimental results to peers, supervisors and customers. It follows that in order to attract more students into STEM careers, students must be provided with meaningful learning experiences that motivate and excite them—learning-experiences that relate directly to the world in which they live. To this end, STEM educators must be capable of providing learning experiences that challenge students to "think outside the box" and apply their knowledge, skills and creativity in solving authentic real-world problems[5-8]. PBL is one educational approach capable of providing this type of learning experience.

PBL in STEM Education

In PBL, students actively participate in their own learning by solving real-world problems in which the parameters are ill-defined and ambiguous. Unlike traditional lecture-based instruction in which students attend lectures and solve well-defined "end-of-chapter" homework problems, PBL is open-ended and contextualized, and student learning is driven by the problem itself. Research shows that compared to traditional lecture-based instruction, PBL improves students' understanding and retention of ideas, critical thinking and problem-solving skills, motivation and learning engagement, and the ability to adapt learning to new situations – skills deemed critical to lifelong learning[9 - 15].

With PBL, students learn the *process* of learning in addition to course content by engaging in a systematic and reflective process that begins with problem analysis, whereby small teams of students work collaboratively to dissect a problem, identifying what is known, what needs to be learned, situational constraints that might apply, and other pertinent problem features required to formulate a solution. Once the problem has been properly framed, students engage in self-directed learning in which they set specific individual learning goals to acquire the knowledge, skills and resources needed to solve the problem. This is followed by brainstorming with peers, in which newly acquired knowledge and ideas are vetted and forged into possible solutions. The final stage is solution testing, where students develop strategies to test and validate their solutions.

While PBL has been adopted in other fields of higher education including business and law, it is only beginning to emerge as an alternative to more traditional approaches in K-12 STEM education. Though not abundant, results from studies of PBL in K-12 STEM education are promising, and even suggest an increased likelihood that at-risk students will succeed academically when provided with alternative learning environments such as PBL[16]. For example, a recent study of girls at risk of failing middle school math or science showed that students had positive reactions to PBL, as evidenced by improvements in their learning processes and self-efficacy[17]. Another study compared the effectiveness of PBL and traditional instructional approaches in developing high school students' macroeconomics knowledge and found PBL to be more effective overall[18]. Interestingly, the results from this study also showed that PBL was particularly effective with students of average verbal ability and below, students who were more interested in learning economics and students who were most and least confident in their ability to solve problems.

Although there is substantial evidence to suggest that PBL can be a valuable supplement to traditional, lecture-based instruction, its effectiveness depends on a variety of factors including variations in the implementation of PBL methods and strategies as well as teachers' knowledge skills and attitudes towards PBL[19,20]. A recent case study described the outcomes of one high school science teacher's exploration of PBL methods in her classroom[21].

> *"For many teachers who have not experienced new methodologies as teachers or as learners, trying a new approach can be intimidating. If PBL is to become more prevalent in K-12 contexts, then teachers will need support and encouragement to try it."*

Given the reported benefits of PBL for preparing today's students with the motivation, problem solving and critical thinking skills needed for careers in STEM disciplines, it is important that pre-service teacher education programs provide aspiring STEM teachers with the knowledge, skills and ability to incorporate PBL methods in their classrooms. Moreover, additional research into the factors affecting teachers' adoption of PBL may prove valuable in promoting more widespread use of this promising pedagogical approach.

The STEM PBL Challenges

To address this problem, the STEM PBL project funded by the NSF-ATE program has created a comprehensive series of multimedia PBL "Challenges" focused on sustainable technologies as well as professional development and training in their use for pre-service and in-service STEM teachers. The STEM PBL Challenges are self-contained multimedia instructional modules designed to develop students' problem solving ability and understanding of sustainable technology concepts and applications. Developed in partnership with industry partners, university researchers and other organizations, the STEM PBL Challenges provide students with authentic real-world problems captured and re-enacted in a multimedia format designed to emulate the real-world context in which the problems were encountered and solved.

Each PBL Challenge contains five main sections: (1) Introduction - An overview of the particular topic to be explored; (2) Organization Overview - An overview of the organization that solved the problem to contextualize the problem; (3) Problem Statement - A re-enactment of the scenario in which the problem was originally encountered; (4) Problem-Discussion - A re-enactment of the brainstorming session engaged in by the individuals who solved the problem; and (5) Problem Solution - A detailed description of the organization's solution to the problem. The Problem Discussion and Problem Solution sections are password protected allowing instructors to control the flow of information and pace of instruction. Each of the five main sections contains additional information and resources (i.e., scripts, websites, spec sheets, etc.) designed to guide the student through the problem solving process. Designed to be implemented using three levels of structure ranging from highly structured (instructor led) to guided (instructor guided) to open-ended (instructor as consultant), the STEM PBL Challenges provide the necessary scaffolds to assist students in the development of their problem solving skills through a developmental continuum[22].

One unique feature of the STEM PBL Challenges is the "Problem Solver's Toolbox." The Problem Solver's Toolbox guides students through a systematic four-phase problem solving approach through a feature called "The Whiteboards." Each of the four Whiteboards, designed to mimic a classroom whiteboard, is broken into several columns with guiding questions to help students break the problem down into more manageable "chunks." The four Whiteboards are described below:

- *Problem Analysis* – What do we know? What do we need to learn? Are there any problem constraints or assumptions?
- *Independent Research* – What are our specific learning goals? What resources will we use? Who on our team will be responsible for learning what? What is our timeline for achieving our learning goals? What learning strategies will we use?
- *Brainstorming* – What ideas do we have for solving the problem? How will we rank them? What solution did we collaboratively agree upon?
- Solution Testing – What is our criteria for a successful solution? How does our solution address each criterion? How could we test our solution? What resources would we need to test out solution?

The Whiteboards help students systematically capture and document their thoughts, ideas, and learning strategies during each stage of the problem solving process. Teacher resources including tutorials, assessment tools, and standards alignments are incorporated into each PBL Challenge as well. Fourteen PBL Challenges have been developed to date in partnership with industry and university partners and are available online at http://www.pblprojects.org.

Knowledge, Skills and Attitudes

The knowledge, skills and attitudes that students bring to learning situations are important factors related to successful learning outcomes. According to Bransford[23] et al, the prior knowledge and understanding students bring with them into new learning situations impacts their ability to build upon and integrate new knowledge with their prior knowledge and understanding. Before learning can occur, students' prior knowledge must first be brought to the surface so that current understanding can be examined, and misconceptions corrected in order to create a solid foundation upon which new knowledge can be built. Second, for students to develop competence in an area of inquiry, they must develop a deep and retrievable base of factual knowledge and organize that knowledge around key concepts. Finally, students must develop the *metacognitive* skills needed to self-direct their own learning, such as how to set learning goals, monitor their learning, evaluate the effectiveness of their learning strategies, and adjust learning strategies when needed.

Accordingly, for aspiring STEM teachers to become successful PBL practitioners, they need to (1) develop a deep and retrievable knowledge base of PBL principles and practice that builds upon their prior knowledge, (2) motivation and confidence to apply their knowledge of PBL methods in the classroom, (3) critical thinking skills needed to facilitate student learning in a PBL environment, and (4) metacognitive skills needed manage their learning and comprehension while acquiring those skills.

In this study, we examined the knowledge, skills and attitudes of pre-service TEE students enrolled in a pre-service course in PBL methods. Five variables were examined; knowledge of PBL principles and practice, motivation, self-efficacy, critical thinking, and metacognitive self-regulation. Motivation refers to the amount of effort a student is willing to commit to a particular learning activity and can vary depending on the value that a student places on the activity. Students who engage in a learning activity out of personal interest in the topic (i.e., learning for learning sake) are said to be intrinsically motivated or mastery oriented. In contrast, students who engage in a learning activity for external rewards such as a good grade or promotion are said to be externally motivated or goal oriented. Research shows that while both motivational orientations are important for successful learning outcomes, students who are intrinsically motivated are more likely to engage in "deep learning" and persist in the face of difficulty[24]. In this study, we defined motivation using two constructs: (1) intrinsic goal orientation – the extent to pre-service teachers are intrinsically motivated to engage in PBL activities for personal gain, and (2) extrinsic goal orientation – the extent to which pre-service teachers are motivated to engage in PBL activities for external rewards (i.e., grade or promotion).

Self-efficacy refers to a student's confidence in his or her ability to be successful in a particular learning endeavor. Research shows that self-efficacy is an important factor related to positive learning outcomes and can moderate the amount of effort learners put forth in achieving specific learning objectives[25]. In this study, we defined self-efficacy as pre-service teachers' confidence in their ability to apply PBL methods in the classroom.

Critical thinking refers to the degree to which students apply previous knowledge to new situations in order to solve problems, reach decisions, or make critical evaluations with respect to performance standards[26]. In order for students to develop critical thinking skills, educators must provide learning experiences that stimulate students' interest and a supportive learning environment that allow for open and meaningful discussions and alternative viewpoints[26]. Accordingly, proponents claim that PBL is ideally suited for improving students' problem-solving and critical thinking abilities. Research shows that PBL can promote the development of students' critical thinking skills[27, 28], increase transfer and application of knowledge[29, 30], and is effective in promoting higher-order thinking[31, 32]. In this study, we defined critical thinking as pre-service teachers' ability to skillfully apply problem solving strategies in solving real-world problems.

Metacognition refers to the awareness, knowledge, and control of cognition[33]. Metacognition is often expressed in terms of two constructs: Metacognitive knowledge and self-regulation. Metacognitive knowledge includes three components: declarative knowledge refers to one's knowledge of specific learning strategies; procedural knowledge involves knowing how to use a particular learning strategy; and conditional knowledge, knowing under what circumstances it is appropriate to use that strategy. Metacognitive self-regulation involves three primary components: planning, monitoring and evaluating. Planning involves activities such as setting learning goals, identifying resources, establishing timelines, and developing strategies for acquiring the desired knowledge. Monitoring involves tracking comprehension and understanding as one reconciles and integrates current information with prior knowledge. Evaluating involves the continuous assessment and adjustment of learning strategies and cognitive activities. Research has shown that metacognitive self-regulation can improve learning outcomes by assisting learners in continuously monitoring and correcting their understanding and comprehension as they engage in a learning task, and is a key factor linked to students' ability to transfer knowledge and skills to new situations [23, 33, 34]. Accordingly, researchers agree that PBL, in which students learn to take responsibility for their own learning, is ideally suited for supporting the development of metacognitive self-regulation[23,35,36]. In this study, we defined metacognitive self-regulation as pre-service teachers' ability to apply specific learning strategies to plan, monitor, and evaluate their learning while solving real-world problems.

Method

This pilot study was conducted during the spring 2011 semester as an observational case study[37, 38, 39.] Quantitative and qualitative measures were applied to better understand how and in what ways does engagement with the STEM PBL Challenges affect pre-service TEE students' (1) knowledge of PBL pedagogy, (2) critical thinking skills and metacognitive self-regulation, and (3) motivation and self-efficacy for applying PBL methods in the classroom?

A total of 14 volunteer (12 male: 2 female) 3rd year pre-service TEE students from a large east coast university enrolled in a 3-credit one-semester technology education PBL methods course (TE-399 Teaching Technology & Engineering K-12). On average, study participants were 23 years old and the majority (71%) had never taken a course in which PBL methods were used.

During the 16-week course, the class was randomly divided into teams of 3-4 students tasked with completing three PBL Challenges. The first PBL Challenge was implemented in a "structured" or cases study mode (~ 2 weeks) in which the instructor worked closely each team to help acclimate them to the PBL process. The second PBL Challenge was implemented in a "guided" mode (~ 3-weeks) in which the instructor played the role of facilitator and students were given more student autonomy to help scaffold the development of their problem solving ability. The third and final PBL Challenge was implemented in an open-ended mode (~ 4 weeks) in which teams had complete autonomy to work through the problem solving process to develop their own solutions. At the end of each PBL Challenge, each team presented their solution to the class and discussed the process they employed in solving the problem. A class discussion followed in which students compared and contrasted their solutions with the PBL Challenge solution.

Three measures were used to answer the research questions:

- <u>Pre-post content knowledge assessment</u> - Pre-post PBL content knowledge was assessed using a PBL content knowledge test (10 open-ended questions) to measure students' understanding of PBL principles and methods. The assessment was developed and scored by a three-member panel of PBL pedagogy experts to ensure content validity and to establish interrator reliability.

- Motivated Strategies for Learning Questionnaire (MSLQ) - The MSLQ is a widely used and validated 81-question Likert-scaled self-report instrument designed to assess college students' motivation and use of learning strategies[40]. Motivation (intrinsic and extrinsic), self-efficacy, critical thinking, and metacognitive self-regulation were measured using selected subscales from the MSLQ. Chronbac's alpha for each variable are reported as *intrinsic motivation* (4 items; α=.74), *extrinsic motivation* (6 items; α=.62), self-*efficacy* (8 items; α=.93), *critical thinking* (5 items; α=.80), and *metacognitive self-regulation* (12 items; α=.79).

- Semi-Structures Interviews – Transcripts from post course semi-structured focus group interviews with students were coded and analyzed to supplement quantitative data and to provide additional insight into issues related to students' reactions to the STEM PBL Challenges with regard to classroom adaption.

Students were invited to participate in the study by volunteering to: (1) complete a pre-post PBL content knowledge test; (2) complete a pre-post online survey (MSLQ); and (3) participate in a focus group interview at the end of the spring 2011 semester. Mean values were computed for each variable from the MSLQ subscales and data were screened for outliers and normality. Paired t-tests were conducted to measure changes in mean scores for each variable. Effect sizes (Cohen's d) were calculated using t-score and sample size to quantify the effect of PBL instruction on the variables in question. To encourage student participation, a cash-prize raffle was held for those students who completed the requirements of the study. The MSLQ was administered using SurveyMonkey® and analyses conducted using SPSS v.19. Researchers were available to respond to any questions or concerns via e-mail, BlackBoard®, and telephone.

Results

Pre-post content knowledge - Pre-post content knowledge tests were scored by a three-member panel of PBL pedagogy experts using a 4-point scoring rubric and converted to a standard 100 point score. Results of paired t-tests showed a statistically significant increase ($t = 7.02$, $p < .001$) in content knowledge. Overall, students demonstrated an increase in their level of knowledge and understanding of the principles and practices of PBL. Students were able to articulate the problem solving process and provided ample evidence of their ability to apply PBL methods and strategies in the classroom. Given that most participants had never taken a course in PBL methods, however, this result was not surprising, though it was positive and encouraging.

Motivation - Results of paired t-tests performed on the MSLQ motivation subscale data ($n = 14$) showed a small statistically insignificant decrease ($t = -.335$, $p= .743$; Cohen's $d = .201$) for intrinsic motivation representing a small effect size. In contrast, while also statistically insignificant, results showed a large increase ($t = 2.014$, $p = .065$; Cohen's $d = 1.343$) representing a large effect size. This result show that while there was a small decrease in intrinsic motivation, the large effect size for extrinsic motivation suggests that students may have been more motivated to engage in PBL by external rewards (i.e., grades) in this course than by personal interest in learning course content. Given that the students in the study were undergraduates enrolled in a required course in their major, they may have been more focused on successfully completing the course requirements in order to graduate than "learning for learning" sake. An alternative explanation may be that because the TEE students had only completed three STEM PBL Challenges, they had not completely internalized the PBL process. In a previous study[22], researchers found that engineering technology students who had completed four or more PBL Challenges showed a greater increase in intrinsic motivation as measured by the MSLQ than students who had completed just two, and had a decrease in external motivation, suggesting that over time and with more experience, external motivation could be internalized, resulting in a transition from a goal orientation to a mastery orientation.

While paired t-test results did not show an increase in intrinsic motivation, analysis of student interview data showed that overall, students were intrinsically motivated by the real world problems posed by the STEM PBL Challenges, and through the opportunity for collaborative learning. Students were asked "Reflecting on your own experience as a learner and as a burgeoning teacher, what was your overall reaction to PBL as compared to traditional instructional methods?" Sample student responses included:

- *"It's a lot more interesting than just the traditional style of teaching, lecturing and just doing assignments. You and your group work on a problem together, figure out what information you need to solve the problem, and then break up the task of finding the information. It's not all fed to you; you have to go look for it. You get to see how a group works or doesn't work if someone doesn't do their part…"*

- *"Being asked to come up with your own solution really plays on your curiosity, and I think that's what I really liked about it."*

These results suggest that engagement with the STEM PBL Challenges helped TEE students develop and internalize the problem-solving process as well as gain an appreciation and understanding of problem-based instructional methods. These results also suggest that the real-world problems presented in the STEM PBL Challenges resulted in a more interesting and meaningful learning experience for students as compared to traditional lecture-based methods, which could potentially improve student engagement in STEM education if implemented by future TEE graduates.

Self-Efficacy **-** Results of paired t-tests on the self-efficacy subscale (n=14) of the MSLQ showed a small but statistically insignificant significant increase (t = .491, p= .632; Cohen's d = .288) representing a small effect size. Paired t-test results were corroborated through analysis of student interview data in which students were asked about their experience with the STEM PBL Challenges. Sample responses include:

- *We did two challenges. We kind of got the hang of things in the first one, and then the second one became a lot easier. I think that the more teachers do this the more students will be independent.*
- *It encourages students to pursue learning through their own learning style. So when they go out and actually do the research on whatever the problem itself is, there could be one kid*

that's more apt to sit down and read an article and another kid who will go search YouTube and watch a video about something. So it allows kids to pursue a similar kind of thing but through their own style.

Overall, these results suggest that students were more confident in their ability to solve real-world problems as a result of completing the STEM PBL Challenges. As with motivation, prior research[22] shows students who had completed four or more PBL Challenges showed higher levels of self-efficacy as measured by the MSLQ than students who had completed fewer than four PBL challenges, suggesting that students' confidence in their ability to engage in real-world problem solving improves with PBL experience. The small improvement in self-efficacy may also be attributed to the constructivist nature of the PBL learning environment. Bandura argued that the type of learning environment and teaching method can improve self efficacy in the classroom[25]. Research suggests that in pre-service teacher education programs, teachers' self-efficacy can be changed through practice that emphasize reflection on one' personal beliefs, hands-on experiences, and engagement in authentic problems[41,42]. In the TE-399 course, pre-service teachers engaged in PBL with a focus on both content and K-12 pedagogy issues. Students worked together in small teams to solve authentic real-world problems dealing with sustainable technologies with the intent on developing the knowledge, skills and motivation to teach PBL in their own classrooms. Students worked collaboratively to frame the problem, identify and acquire the knowledge and resources needed to solve the problem, shared different perspectives, conducted independent research, brainstormed ideas, and converged on a problem solution that represented the collective effort of the group. They also discussed their beliefs and concerns about how to implement PBL in the classroom. By doing so, engagement with the STEM PBL Challenges may have served as a catalyst for improving pre-service teachers' self-efficacy beliefs about employing PBL methods in their classrooms.

<u>Metacognitive Self-Regulation</u> - Results of paired t-tests on the metacognitive self-regulation subscale (n=14) of the MSLQ showed a statistically significant increase ($t = 2.375$, $p = .034$; Cohen's $d = 1.514$) representing a large effect size. These results suggest that overall, students' metacognitive self-regulation improved as a result of completing the PBL Challenges.

Results of paired t-tests were corroborated through analysis of student interview data, in which students were able to clearly articulate the process by which they would solve a problem. Student comments previously cited provide evidence of metacognitive self-regulation, In their responses, described the problem solving process in terms of reflecting on their current understanding of the problem and its parameters, identifying knowledge gaps, and planning strategies for implementing and testing their solution – all key attributes of metacognitive self-regulation. As students collaboratively engaged in problem-solving by completing the four Whiteboards, they reflected upon and were able to elucidate their current state of understanding, their thought processes, and problem solving strategies. Research shows that verbalizing the thought process while engaging in problem solving improves metacognition, an essential component of effective problem solving[23]. Furthermore, upon completion of each PBL Challenge, students were required to complete a reflective journal which required students to provide a detailed summary and critical analysis of the problem-solving process employed in solving the PBL Challenge. Researchers maintain that this final reflective exercise is essential in the development of effective metacognitive and problem-solving skills[24].

Critical Thinking - Results of paired t-tests performed on the critical thinking subscale (n=14) of the MSLQ showed a statistically significant increase (t = 4.337, p= .001; Cohen's d = 2.762) representing a large effect size. These results were corroborated through analysis of student interview data, in which students articulated their thought process in solving a problem. Sample student responses included:

- *"It makes the students think a little more critically about solving problems. The great thing about it is that they come up with their own solutions…and what they feel is the best solution to the problem at hand. They're taking concepts they've learned in other classes and applying it in solving a real-world problems…"*

- *"With the watershed problem, they wanted to keep it as cost effective as possible, so that required you to be a little more creative with your solutions. And I know in the group that I had we came up with many creative solutions, but again, there isn't just one right solution. And that's what I think is good about it, there isn't just one right way, you have to incorporate each other's ideas in one way or another in order to successfully solve the problem."*

As described earlier, critical thinking involves the degree to which students apply previous knowledge to new situations in order to solve problems, reach decisions, or make critical evaluations with respect to performance standards[26]. It is clear from these student comments that engagement with the STEM PBL Challenges provided a valuable learning experience in which students were able to draw from and synthesize prior knowledge acquired in other classes, from their own research and that of their peers, and were able to converge on a problem solution that addressed the specific performance criteria – consistent with the definition for critical thinking.

Conclusion

In this paper, we presented the results of a pilot study conducted to examine the effect of a model PBL methods course on the knowledge, skills, and attitudes of pre-service K-12 STEM educators. During the spring 2011 semester, 14 pre-service TEE students enrolled in an east coast university teacher education program participated in a PBL methods course in which they completed three STEM PBL Challenges over the course of a 16-week semester. Qualitative and quantitative methods were used to assess students' motivation, self-efficacy, critical thinking, and metacognitive self-regulation using selected scales from the Motivated Strategies for Learning Questionnaire (MSLQ). Data were corroborated through post-course focus group interviews with students. Results of pre-post assessments showed overall gains in extrinsic motivation, self-efficacy, critical thinking and metacognitive self-regulation, While measures for intrinsic motivation showed a slight statistically insignificant decrease, measures for metacognitive self-regulation and critical thinking showed statistically significant increases with large effect sizes. Pre-post assessment of content knowledge with regard to PBL methods was also significant.

The results of the pilot study suggest that through engagement with the STEM PBL Challenges in the TE-399 PBL methods course, pre-service TEE students developed a deep and retrievable knowledge base of PBL principles and practices that built upon prior knowledge, motivation and confidence to apply their knowledge of PBL methods in the classroom, the critical thinking skills needed to facilitate student learning in a PBL environment, and the metacognitive skills needed manage their learning and comprehension while acquiring those skills. While the results are encouraging, given the small sample size, lack of a control group and other threats to internal validity, the generalizability of this pilot study are limited to the study's population. Future studies should include a larger sample size and an experimental or quasi-experimental design to improve internal validity and generalizability.

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