INFUSING PROBLEM-BASED LEARNING (PBL) INTO SCIENCE METHODS COURSES ACROSS VIRGINIA

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Abstract

This article outlines the results of a collaborative study of the effects of infusing problem-based learning (PBL) into K-12 science methods courses across four universities in Virginia. Changes in pre-service teachers' attitudes surrounding science teaching were measured before and after completing a science methods course in which they experienced PBL first-hand as participants, and then practiced designing their own PBL units for use in their future classrooms. The results indicate that exposure to PBL enhances pre-service teachers' knowledge of inquiry methods and self-efficacy in teaching science.

Introduction: Why Incorporate Problem-Based Learning into Science Methods Courses?

A growing number of students in the United States find it difficult to connect science content and skills to real-world scenarios, indicating a true lack of understanding. The most recent Program for International Student Assessment revealed that fifteen-year-olds in the United States could not apply scientific knowledge and skills to real-world issues as well as their peers in sixteen of twenty-nine countries [1]. Data on science achievement in higher education are similarly concerning. The United States now ranks 27th among industrialized countries for the number of students who receive bachelor's degrees in science or engineering [2].

Regardless of the reasons, it is clear that science is not engaging many students. *Rising Above the Gathering Storm Revisited* focused on mathematics, science, and engineering not only because they are essential to job creation, but also because the committee *concluded that* "these

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are the disciplines in which American education is failing most convincingly" [2]. These data, combined with other performance indicators, led the committee to assert "for the first time in history, America's younger generation is less well-educated than its parents" [2].

Based on indicators of students' poor performance in science, it comes as little surprise that research reveals students view school science as neither popular nor pertinent [3]. Science education must do a better job of engaging students. Science is no longer just for "future scientists." Today, every student needs a strong foundation in scientific content and process skills. While not all students will go into science fields, all are members of a global society. Individuals can no longer be unaware of how their actions or inactions impact others near and far. The goal of science education must be that of producing scientifically literate citizens. Such citizens would be able to actively participate in decisions on issues that impact their lives, such as: waste disposal, experimental medical treatments, water quality, and other issues of personal health and safety (socio-scientific issues). To do this, they need to have the skills to examine problems, ask important questions, develop plans for collecting evidence, analyze data, communicate and work with others as they propose solutions, and think critically to reflect on choices made.

Jobs in Science, Technology, Engineering, and Mathematics (STEM) are projected to be the most abundant careers of the foreseeable future [4]. Science educators in Virginia especially need to focus on equipping students with STEM skills because in 2005, 40% of STEM jobs were located in Virginia and five other states [5]. In addition to anticipated job growth in these fields, workers will also be needed to replace those retiring from STEM careers. These jobs would require workers to apply content and skills to real-world problems, the very knowledge and skills on which U.S. fifteen-year-olds students scored so poorly in 2009.

Scientific process skills, much like the skills of a professional athlete, are acquired through sustained and targeted practice, not by sitting behind a desk. Instead of telling students how they will use the information one day, science educators must provide experiences that allow students to apply it now in a meaningful way. For many, this requires a paradigm shift in the way science is taught. This is why inquiry and problem-based learning (PBL) are essential.

Literature Review—What Is PBL?

Problem-based learning (PBL) can be traced back to Dewey's emphasis on learning by doing and thinking [6]. He argued that learning "should give students something to do…and the doing is of such a nature as to demand thinking or intentional connections" [6]. As early as 1965, Gagné noted PBL's effectiveness in developing science concepts [7]. McMaster University's medical school implemented PBL because of concern over the limited application skills of many of their recent graduates [8].

Implementation of PBL in the K-12 setting has recently gained international attention as a way to provide creative inquiry that fosters critical thinking and is aligned with students' interests and abilities [9]. It is a learning approach that allows for individual flexibility in learning and the social construction of knowledge. Aligned with Vygotsky's theory of constructivism, PBL pushes students to connect prior knowledge with a current problem and solve it in their own way. The American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the Virginia Mathematics and Science Coalition's (VMSC) visions of inquiry-based and student-centered science is supported by PBL [10-12].

Virginia Initiative for Science Teaching and Achievement (VISTA) researchers define problem-based learning (PBL) as "students solving a complex problem with multiple solutions over time like a scientist in a real-world-context" [13]. They further state the problem must be meaningful to students and is typically embedded in a course of study from one to five weeks in duration [13]. Through PBL, students ask scientific questions relevant to their lives, collect evidence, and develop explanations based on the evidence obtained. This type of inquiry provides students with the highest level of investigative control, unlike traditional teacher-led explorations [14]. Students use "The Problem-Solving Cycle," which was created by Sterling in 2005 as a roadmap throughout their PBL investigations [13]. Contrary to the lockstep myth of "The Scientific Method," The Problem-Solving Cycle allows students the flexibility to move forward or retrace their steps in the investigation as needed. This enables student researchers to backtrack in response to new information gained and better represents the way scientists work to find solutions in their profession.

Literature Review—Research Findings on PBL

Much of the early research on PBL implementation pertains to medical school students. More recent research examines the impact of PBL in the K-12 and post-secondary settings, yet research in this area is still in the early stages [15]. The current study seeks to identify the potential benefits of PBL on pre-service teachers and their future practice so the following literature review focuses on research relevant to this study.

Benefits to Students: Affective — Culturally responsive pedagogy, such as PBL, allows students the flexibility to customize their own learning. Sterling reported students (grades 4-6) involved in a PBL camp showed an increase in positive attitudes toward science on pre- and post-attitudinal surveys [16]. Students indicated that the opportunity to shape the inquiry to meet their abilities and interests made them feel more empowered [16]. Increased confidence may change the way students think of science and a possible career in science as evidenced by findings from Sterling, Matkins, Frazier, and Logerwell who reported greater interest and more positive views of science among PBL participants [17]. Similarly, PBL was found to positively impact post-secondary students' attitudes toward the learning environment relative to peers in a traditional program [18].

Osborne and Collins found that students want more experience in authentic work, longer inquiries, and more time to discuss these experiences, all components of PBL [3]. Their research with nine- to fourteen-year-olds concluded that school science lacks "relevance and greater autonomy" [3]. Relevance and autonomy have been linked to motivation [19]. Research with students of varying ages trained in PBL found that students had increased motivation [16, 20-21].

Benefits to Students: Elementary/Middle Cognitive — More recently, Frazier and Sterling conducted a mixed-methods study on their PBL summer camps for students aged nine to twelve [22]. The camps were offered across a three-year period and included 116 participants designated as at-risk by their schools. The researchers examined student artifacts, teaching curriculum, and students' performance on pre- and post-science content assessments. They found students "experienced significant growth in their science content knowledge and skills" [22]. Further research with elementary students support Frazier and Sterling's findings [15, 23-24]. Drake and Long also determined that PBL students were better able to create problem-solving strategies than students in a comparison group [15].

Benefits to Students: Middle and Secondary Cognitive— Studies provide conflicting reports of the degree of student academic performance related to PBL implementation. Results of PBL implementation in a grade 11 chemistry class revealed PBL positively impacted students' achievement and helped address misconceptions in a significant way [20]. Additionally, PBL was found to promote test success in science among twelve- and thirteen-year-olds according to Wong and Day [21]. Research documents evidence of academic success of students in other content areas taught through PBL [25]. Gallagher and Stepien found students in American studies performed at least as well on multiple choice tests as students taught traditionally [25].

Benefits to Students: Post-Secondary/Professional Cognitive — An analysis of the performance of biochemistry students taught through PBL revealed a greater depth of understanding of the material than those in a traditional program [26]. Pre-service teachers taught in a PBL methods course showed increases in pedagogical content knowledge about modeling activities [27]. Etherington's work with pre-service teachers demonstrated that PBL fosters academic risk taking and resulted in intellectual gains in science [28].

Benefits to Students: Social — Interviews were conducted with chemistry PBL students to determine their beliefs according to PBL activity. The findings, according to the interviews, revealed that students in the PBL class were more motivated, self-confident, willing to problem solve and share knowledge, and were more active in cooperative group activities than students of traditional instruction [20].

Benefits to Teachers: Time on Task — Students in the PBL experimental classroom spent 4.27 more minutes on task of each 45-minute class period relative to the comparison group. The cumulative effect of this daily increase in time on task equates to 21.35 minutes of science engagement per week, and 12.80 hours of science over the course of the school year [15].

Benefits to Teachers: Professional Confidence — Teachers who lack confidence and comfort with a student-centered approach tend to fall back on traditional modes of teaching, leading to marginal learning [29]. Teachers who were trained in PBL and provided with ongoing coaching showed improved confidence in their ability to use problem-based instruction [28].

Benefits to Teachers: Student Behavior — Self-determination theory states that students have three academic needs: competence, relatedness to others, and autonomy. In PBL, teachers serve as facilitators who enhance student autonomy and engagement [30]. Perceived autonomy is a major predictor of engagement in learning and school achievement [31]. Engaged students are intrinsically motivated and less likely to become classroom management problems.

Literature Review—Obstacles to PBL Implementation

Learning and utilizing PBL requires time and commitment from teachers and students. Wong and Day reported expected resistance at the beginning of PBL development in science education and other areas [21]. Changing the pedagogy of science is problematic because many teachers lack the skills and confidence needed to lead discussions and manage student-directed classrooms [28, 32]. Etherington reported some pre-service teachers became antagonistic when forced to work on critical thinking and open-ended PBL [28]. Goodnough found teachers often needed coaching in PBL problem design [32]. Other obstacles related to the adoption of PBL center around time and standardized testing concerns. Research documenting the academic performance of PBL students has begun to address standardized testing concerns [20-22, 25].

Literature Review—Summary

Problem-based learning offers students the opportunity to take control of their learning. Studies indicate students across grade levels respond favorably to this type of investigative autonomy [3, 16, 21]. Research on academic gains related to PBL report positive findings, but the degree of improvement varies [15, 20-24, 27, 28]. More research is needed on the impact of PBL in varying grade levels and subject content areas.

While questions remain about the degree of the academic impact of PBL, all studies reviewed reported positive impact in the affective domain [16-18, 21]. Students of PBL reported feeling empowered and more interested in the learning environment. Furthermore, social impact was often cited as a positive aspect of PBL implementation. Data revealed students were more willing to share knowledge and participated more actively in cooperative learning than peers in a traditional setting [20].

Institutional and personal impediments to PBL implementation exist. Driven by high-stakes testing, school divisions often lack flexibility in schedules and instructional strategies utilized by teachers. The issue of training and continued professional support adds an additional burden to the already overscheduled school day. On an individual level, resistance to PBL instruction was noted among teachers. Teachers expressed concerns over their ability to manage behavior and lead essential discussions in a student-centered classroom.

Today's students do not see classroom science as popular or related to the real world. Traditional lecture methods have not engaged students in a meaningful way. Problem-based learning shows promise as an instructional method capable of connecting students with science. For teachers to be equipped to teach PBL science, they must be exposed to science methods courses that model this strategy.

Methodology—Introduction

Though the use of PBL has been widely studied through the lens of improving student outcomes and achievement at the K-12 level, little work has been done in studying the use of PBL as a means of preparing pre-service teachers to teach science in their future classrooms [16, 22, 33]. To address this gap in the literature, four university-based science educators from three institutions of higher education across Virginia engaged in a collaborative study to investigate the value-added effects of infusing PBL methodology into their respective elementary, middle, and secondary science methods courses taken by pre-service teachers as part of professional education preparation programs.

Methodology—Participants

The study was facilitated at all three institutions during the 15-week instructional period of the Fall 2011 semester. During the pre-test, a total of twenty-nine pre-service teachers from across the institutions participated in the study, including twenty-one pre-service elementary school teachers and eight pre-service middle/secondary science teachers. During the post-test, a total of twenty-five pre-service teachers from the pre-test participated in the study, including seventeen pre-service elementary school teachers and eight pre-service middle/secondary science teachers. Table 1 provides a breakdown of demographic data of the participants.

Table 1
Demographic Data for Pre-Test (*N*=29) and Post-Test (*N*=25)

Demographic	Pre-Test *N*	Post-Test *N*
Male	1	1
Female	28	24
Total	29	25
African-American	9	5
Caucasian	20	20
Total	29	25
Elementary	21	17
Secondary	8	8
Total	29	25

Methodology—Research Questions

In order to gather the information necessary, the following research questions helped guide the research:

1) What are pre-service teachers' perceptions of delivering problem-based learning?
2) How do pre-service teachers differ on personal science teaching efficacy beliefs and science teaching expectancy outcomes with respect to elementary and secondary pre-service teaching?

Methodology—Instrumentation

In all methods courses, study participants completed a survey developed by Enochs and Riggs (1990) known as the Science Teaching Efficacy Belief Instrument (STEBI-B) [34]. The STEBI-B was developed as a survey to evaluate pre-service teachers' self-efficacy toward teaching science. The instrument was based around Bandura's social learning theory, and consists of two constructs: Personal Science Teaching Efficacy (PSTE), and Science Teaching Outcome Expectancy (STOE) [35]. The STEBI-B has a reliability rating of .90 (PSTE) and .76 (STOE), making it a reliable instrument. The instrument utilizes a 5-point Likert scale ("Strongly Agree" – "Strongly Disagree"). Enochs and Riggs suggest that the following numbers, 5 = Strongly Agree, 4 = Agree, 3 = Undecided, 2 = Disagree, and 1 = Strongly Disagree, correspond with responses [34].

Methodology—Procedure

During the first week of the courses, pre-service teachers were given the STEBI-B as a benchmark indicating their self-efficacy with respect to their ability to teach science. During the course of the semester, the pre-service teachers participated in PBL activities facilitated by their course instructors, and then were tasked with developing their own PBL units for use in their future science classrooms. The STEBI-B survey was administered again during the final week of the course to detect any changes in the pre-service teachers' self-efficacy which could potentially occur as a result of their exposure to PBL methodologies infused into the methods courses.

Methodology—Analysis of Results

This study was completed during the Fall 2011 semester at three institutions. In the study, descriptive statistics and an analysis of variance (ANOVA) were conducted to address the research questions.

Research Question 1: What are pre-service teachers' perceptions of delivering problem-based learning? To address this question, the researchers conducted descriptive statistics to display pre-service teachers' perceptions prior to the delivery of coursework toward teaching problem-based learning and after the coursework was completed. Prior to coursework, pre-service teachers scored toward undecided (M = 3.53, SD = .539) on personal science teaching efficacy (PSTE) and moderately low as well on science teaching outcome expectancy (STOE) (M = 3.50, SD = .437). For pre-service teachers, results from the post-tests suggest that pre-service students perceived themselves to be moderately high in personal science teaching efficacy (PSTE) (M = 4.13, SD = .413) as a result of the coursework. Furthermore, while their science teaching outcome expectancy (STOE) was not as high (M = 3.87, SD = .564), there was a small gain from the pre-tests. Moreover, the effect size, using Cohen's d, were computed to identify practical significance of the differences between the pre-tests and post-tests [36]. The pre-tests and post-tests revealed strong effects on PSTE (d = 1.019) and STOE (d = 1.109). Means, standard deviations, and effect size are displayed in Table 2.

Table 2
Descriptive Statistics on Pre-Test (N = 29) and Post-Test (N = 25)

Subscale	Pre-Test *M*	Pre-Test *SD*	Post-Test *M*	Post-Test *SD*	Effect Size *d*
PSTE	3.53	.539	4.13	.413	1.019*
STOE	3.50	.437	3.87	.564	1.109*

Note: Effect size strength was determined using Cohen's breakdown for small (d = .20-.49), moderate (d = .50-.79), or strong (d = .80 or higher) [36].
*Strong effect.

Research Question 2: How do pre-service teachers differ on personal science teaching efficacy beliefs and science teaching expectancy outcomes with respect to elementary and secondary

pre-service teaching during the post-test? A one-way analysis of variance (ANOVA) was run, in which elementary pre-service teachers and secondary pre-service teachers did not differ significantly on PSTE because the p value was greater than .05 and .001 levels at $F\ (1,24) = 3.137$, $p <$ no significance. Post-test results revealed significance on the subscale STOE between elementary pre-service teachers and secondary pre-service teachers at $F\ (1, 24) = 4.655$, $p < .05$ level, with a higher mean for elementary pre-service teachers. Table 3 summarizes the results of the analysis of variance on PSTE and STOE of the STEBI-B post-test.

Table 3
Analysis of Variance on Elementary Pre-Service and Secondary Teachers

Source	*SS*	*df*	*MS*	*F*	*p*
			Between Groups		
PSTE	.491	1	.491	3.137	.090
STOE	1.285	1	1.285	4.655	.042*
			Within Groups		
PSTE	3.598	23	.156	3.137	.090
STOE	6.349	23	.276	4.655	.042*

Note: *p<.05

Methodology—Summary

Data revealed that students initially did not perceive themselves as capable of delivering problem-based learning prior to their training. The participants were undecided in whether they could perform problem-based learning at an acceptable level. However, the data did reveal that the coursework improved their understanding of PBL and enhanced their self-efficacy toward delivering this method of instruction in a science class. Furthermore, pre-service teachers felt they were capable of getting their future students to obtain student outcomes toward problem-based learning.

Discussion

Perceived Science Teaching Efficacy — Pre-data revealed participants were undecided about their abilities to effectively teach and engage students in science. Post-data showed that pre-service teachers gained confidence in their science teaching abilities throughout their experience with PBL. This finding is significant because teacher confidence is directly related to the type of instruction found in the classroom. Teachers who lack confidence are more likely to focus on teacher-directed instruction that can marginalize students and minimize learning [29]. With the current emphasis on student-led inquiry, science teachers must be confident enough to relinquish some of the decision-making duties and provide students with a more active role in their science education [10-12]. Data from this study indicate PBL training was effective in strengthening participants' confidence in teaching science. This finding suggests PBL-infused science methods courses are of value in informing pre-service teachers' PSTE and potentially impacting how science will be taught in their future classrooms.

Effectively implementing a particular instructional model takes time and practice. It is essential for pre-service teachers to observe a master teacher modeling PBL so they know what true PBL looks like. Additionally, pre-service teachers must be provided the opportunity to be students of PBL in order to judge first-hand the impact of learning science in that manner. With the awareness that PBL implementation presents challenges for many beginning and experienced teachers, science methods educators should model the role of facilitator by asking probing and guiding questions and fostering student-led inquiries. This type of science methods instruction will help students learn content and learn how to learn. Teachers must have a strong Pedagogical Content Knowledge (PCK) to model for students. Similarly, teachers in training need science education professors to model a strong PCK for them. Findings from this study align with work by Van Driel and DeJong who determined pre-service teachers' PCK improved when taught in a PBL format [27]. Etherington reported intellectual gains for pre-service teachers who engaged in PBL learning [28]. This supports findings for the current study because students who gain intellectual understanding of content would be expected to show improvements in beliefs about their abilities. While the initial improved confidence found in the current study is of interest, it is important to remember the importance of ongoing professional coaching to maintain confidence and effective implementation of PBL.

Science Teaching Outcome Expectancy — Prior to PBL methods courses, participants reported they were somewhat undecided about how their teaching might impact student learning. Post-data indicated improvement in participants' STOE values that is of practical significance. These findings add additional strength to the call for PBL-infused science methods courses. Pre-service teachers' views of their abilities to impact student learning grew after PBL coursework. For these reasons, science education faculty should incorporate PBL into their courses in order to help future teachers develop skills and confidence in PBL implementation.

Furthermore, data from this study found pre-service elementary and secondary teachers did not differ significantly in their PSTE post-test scores. The fact that pre-service elementary teachers felt as confident as pre-service secondary teachers in science instruction is important because most elementary science teachers are not science majors. It stands to reason that teachers with a science background will feel more confident teaching science than teachers without a science background. The fact that PBL played a part in pre-service elementary majors becoming more confident in their ability to teach science is an interesting finding that warrants further investigation.

Pre-service elementary and secondary teachers were found to have significant post-study differences on the STOE, with elementary pre-service teachers yielding a higher mean. This finding is important because elementary teachers as a whole tend to report a lack of confidence and/or interest in science instruction. If pre-service teachers taught via PBL grow in the belief that they can positively impact student learning, they are more likely to show an interest and enthusiasm for science that will come across to their students. Teachers who feel capable and empowered are more likely to produce capable and empowered students.

Diversity continues to increase among today's students. The diversity of the classroom teacher is not keeping up with that of the larger population. The majority of educators continue to be white females. Diverse instructional strategies present a method of addressing the social and cultural differences that exist between teachers and students. When students are able to lead their own science inquiries, the experiences will be much more relevant, meaningful, and motivating. Problem-based learning offers a means for highly effective science instruction that is culturally responsive.

Implications for Education

This initial study provided a foundation for infusing PBL strategies into pre-service science methods courses spanning the K-12 level offered by multiple institutions of higher education across Virginia. Though the study was relatively small in terms of the number of participants, the impact of the findings can be extended to a wider educational context.

Preliminary results indicate that the benefits of employing problem-based learning strategies at all levels of science education are numerous for all parties involved, and the science education community as a whole should continue to embrace and support this emerging methodology of science instruction.

Suggestions for Best Practices in Pre-Service Learning

Based on the preliminary results of this study, the following suggestions for best practices in pre-service science learning have been identified:

- **Pre-service science teachers should be given the opportunity to participate in authentic problem-based learning scenarios as part of their own science education—** Since PBL methods likely differ from the traditional methods many pre-service teachers experienced during their own K-12 science education, it is crucial to allow prospective teachers to experience PBL in order to convince them of its added benefit of exploring the world in a scientific way. In addition, first-hand experience will increase their comfort level with PBL methods.

- **In introducing PBL strategies into science methods courses, instructors should make thoughtful linkages between PBL methodology and other successful constructivist methodologies in science education—**For example, the four phases of developing effective PBL scenarios are very compatible with the stages of the learning cycle, which may be more familiar to pre-service teachers [37]. Though the benefits of employing PBL methods within science classrooms across Virginia are becoming apparent, it is important to keep in mind that PBL did not emerge without a solid grounding in constructivist learning theory [38].

- **Pre-service science teachers should be given the opportunity to practice designing PBL units for use in the classroom, ideally with the opportunity to implement their units in the classroom in cooperation with veteran K-12 teachers—**Pairing pre-service and in-service teachers to implement PBL units in science classrooms benefits both the pre-service teachers and in-service teachers in multiple ways. In working with veteran teachers, pre-service teachers are afforded the intuition and guidance of experienced teachers as they design their units. Even if a veteran teacher has not used PBL strategies in the past, s/he possesses the pedagogical content knowledge to discern whether an activity is appropriate for the students, as well as whether it will be an effective way for them to learn the content at hand. In working with pre-service teachers who have received instruction in PBL methods, veteran teachers gain exposure to new pedagogy that may be unfamiliar or seem chaotic at first glance. Having experienced PBL methods as a way of approaching an authentic problem first-hand, the pre-service teachers can offer support to veteran teachers in implementing PBL instruction, and offer suggestions for providing support to students throughout the course of the unit without resorting to direct instruction.

Promoting Awareness of PBL: Removing Obstacles

One of the primary challenges to the widespread use of PBL methodology in K-12 schools is the prevalent perception that there is not enough time to do so. If we solidly believe in the value-added benefits of PBL as a means for empowering science students to establish cross-thematic connections between science concepts, then we must work together as a science education community to convince educators, administrators, colleagues, and parents that the additional time, if any, required to implement PBL units in science classes is more educationally valuable to students than methods of direct instruction. It is also important to wholly support K-12 educators in doing so. There are several initial ways to approach this formidable task:

- **We must link PBL units to the Virginia *Standards of Learning* (*SOL*) explicitly**—In designing PBL units for use in K-12 science classrooms, we must be sensitive to the time constraints experienced by classroom teachers at all levels, and duly acknowledge these concerns by making sure that PBL scenarios embody a multitude of science *SOL* that would otherwise need to be covered as a means of justifying the use of class time to complete the PBL unit.

- **Design cross-disciplinary PBL units which encourage cooperation between teachers of different disciplines**—Sharing the development and implementation of PBL units across multiple classrooms at all levels can ease the burden of class time required to complete the unit. Additionally, having students approach the same problem from different disciplinary lenses encourages the type of global thinking which PBL aims to engender.

- **Make PBL a focal point of pre-service science teacher education**—By providing support in learning how to effectively implement PBL to the next generation of science teachers, the science education community can help make pre-service teachers become more comfortable in employing a methodology which they did not experience as students themselves. Thus, the science education community is making strides in combatting the old adage that "we teach the way that we were taught," and promoting real reform in science education. These pre-service teachers will be equipped to become the PBL experts in their future schools, providing a support network to veteran teachers in implementing PBL strategies in their classrooms.

Future Directions of PBL

Though preliminary results of this study and others are favorable in terms of the widespread use of PBL in science education, continued study of PBL is needed, particularly in the area of the effects of the infusion of PBL methodology in pre-service science teacher education. Future directions include further study of PBL in pre-service, K-12 science teachers across Virginia via a lesson study model in order to investigate how pre-service science teachers implement PBL units in their first classrooms, and how their use of PBL evolves over time.

One of the limitations of the current study was the use of the STEBI-B as the primary tool for identifying changes in teacher self-efficacy as a result of instruction in PBL methodology. Though this instrument is known to be flawed, locating and designing more accurate instruments to capture such subtle and personal teacher characteristics is difficult. In future studies, a more qualitative model could provide a more detailed description of the impact of PBL on pre-service teachers' transitions to the science classroom.

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