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# EFFECT OF STRUCTURE IN PROBLEM BASED LEARNING ON SCIENCE TEACHING EFFICACY BELIEFS AND SCIENCE CONTENT KNOWLEDGE OF ELEMENTARY PRESERVICE TEACHERS

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PRESERVICE TEACHERS

By

Selena Kay Sasser

A Dissertation
Submitted in Partial Fulfillment of the Requirements for the
Doctor of Philosophy Degree

Department of Curriculum and Instruction
in the Graduate School
Southern Illinois University Carbondale
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DISSERTATION APPROVAL


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AN ABSTRACT OF THE DISSERTATION OF

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MAJOR PROFESSOR:  Dr. Kevin C. Wise

This study examined the effects of differing amounts of structure within the problem based learning instructional model on elementary preservice teachers' science teaching efficacy beliefs, including personal science teaching efficacy and science teaching outcome expectancy, and content knowledge acquisition.

This study involved sixty undergraduate elementary preservice teachers enrolled in three sections of elementary science methods classes at a large Midwestern research university.  This study used a quasi-experimental nonequivalent design to collect and analyze both quantitative and qualitative data.  Participants completed instruments designed to assess science teaching efficacy beliefs, science background, and demographic data.

Quantitative data from pretests and posttests were obtained using the science teaching efficacy belief instrument-preservice (STEBI-B) developed by Enochs and Riggs (1990) and modified by Bleicher (2004).  Data collection instruments also included a demographic questionnaire, an analytic rubric, and a structured interview; both created by the researcher.

Quantitative data were analyzed by conducting ANCOVA, paired samples *t*-test, and independent samples *t*-test.  Each of the treatment groups received the same problem scenario, one group experienced a more structured PBL setting, and one group experienced a limited structure PBL setting.  Research personnel administered pretests and posttests to determine the elementary preservice teachers' science teaching efficacy beliefs.

The results show elementary preservice teachers' science teaching efficacy beliefs can be influenced by the problem based learning instructional model. This study did not find that the amount of structure in the form of core ideas to consider and resources for further research increased science teaching efficacy beliefs in this sample. Results from the science content knowledge rubric indicated that structure can increase science content knowledge in this sample. Qualitative data from the tutor, fidelity raters, and interviews indicated the participants were excited about the problem and were interested in the science content knowledge related to the problem. They also indicated they were motivated to continue informal study in the problem area. Participants indicated, during the interview, their initial frustration with the lack of knowledge gained from the tutor; however, indicated this led to more learning on their part.

This study will contribute to the overall knowledge of problem based learning and its structures, science teaching efficacy beliefs of elementary preservice teachers, and to current teaching and learning practices.

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**CHAPTER 1**

**INTRODUCTION**

In the early 1990s, a national conversation emerged emphasizing a scientifically literate society. Science processes and identification of core concepts in science were at issue. The National Science Teachers Association (NSTA) (1996) advocated that elementary children should be equipped with critical thinking and problem solving skills, both of which are most easily gained through science. It was acknowledged that science practice skills, known as science processes, were as important as science content for a scientifically literate society to be able to evaluate and solve everyday personal problems (National Research Council [NRC], 1996). To accomplish this national vision, elementary teachers needed to teach science differently. Teaching science content, alone, would no longer be adequate for the elementary science classroom. Science process skills that build on elementary students' "natural curiosity and common sense knowledge" (Schwartz, Abd-El-Khalick, & Lederman, 1999, p. 3) would have greater emphasis. Duschl, Shouse, and Schweingruber (2008) emphasized science processing skills by "building theories and models; collecting and analyzing data from observations or experiments; constructing arguments; and using specialized ways of talking, writing, and representing phenomenon" (p. 47).

The NRC (2012) released *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The framework "identifies key scientific ideas and practices all students should learn by the end of high school" (The National Academies, 2011). The Framework lays the groundwork for the new K-12 science education standards and replaces those developed in the 1990's, including the National Science Education Standards (NSES)

(NRC, 1996) and Benchmarks for Science Literacy, known as 'Benchmarks' (American Association for the Advancement of Science [AAAS], 1993).

In April, 2013, the National Academy of Sciences (NAS), Achieve, AAAS, and NSTA released the *Next Generation Science Standards* (NSTA, 2013). The standards highlight science processes and science concepts for students beginning with kindergarten and progressing through grade 12.

In addition to *teaching* science appropriately, teachers also need to *learn* science appropriately. So often, content knowledge is taught without elementary teachers having an adequate understanding of the discovery process that makes science exciting. The standards require teacher development and teacher education programs that place a greater emphasis on helping elementary teachers not only learn science concepts, but also learn best practices (Next Generation Science Standards, 2012). In addition, the NRC (2012) states,

> Teaching science as envisioned by the framework requires that teachers have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation of how scientists collaborate to develop new theories, models, and explanations of natural phenomena. Rarely are college-level science courses designed to offer would-be science teachers, even those who major in science, the opportunity to develop these understandings. (p. 256)

Many studies recognize elementary teachers are lacking sufficient science content knowledge to effectively teach science (Friedl, 1997; Palmer, 2002; Weiss, 1994). Van Aalderen-Smeets, Walma van der Molen, and Asma (2012) reported that "primary school teachers are not adequately trained to teach science" (p. 159). A feeling of inadequacy and discomfort in teaching science is felt in both inexperienced and experienced teachers (Abell &

Roth, 1991).  Bencze and Hodson (1999) correlated a lack of confidence in science content knowledge with a decreased likelihood to teach science.

Hodson (2003) reported that as teacher enthusiasm and confidence in science increased, science teaching time, hands-on experiences, and encouragement of student-led activities increased.  Corrigan and Taylor (2004) believed preservice teachers' confidence could be enhanced through a self-regulated learning environment in which they "undertake the whole learning process, including researching a topic and implementing an activity-based, investigative task".  Such a learning experience can be achieved using the problem based learning instructional model (PBL).

Dr. Howard Barrows developed the problem based learning instructional model when he was a faculty member of the health sciences at McMaster University.  Further development and study was conducted at Southern Illinois University Medical School.  Although the model was initially used to train medical students, it is now practiced in many health fields, K-12 schools, and with undergraduates and graduates in an ever-increasing number of content areas.  As defined by Barrows (1996), the model is student centered; therefore, teachers act as facilitators and guide students as needed.  Students work collaboratively to learn content knowledge and problem solving skills through interacting with and solving real world, complex problems that engage and focus their learning.

The PBL model is founded on the constructivist learning theory, which states, "learners construct knowledge based on what they already understand as they make connections between new information and old information.  Students' prior ideas, experiences, and knowledge interact with new experiences and their interpretations of the environment around them" (D'Angelo et al., 2009).   An instructional program based on constructivist learning theory should

acknowledge: 1) a student's prior knowledge and understanding affects future learning, 2) students construct meaning through classroom interaction with others, and 3) construction of knowledge should be around core concepts (Brooks & Brooks, 1999). The Barrow's model of problem based learning accomplishes these key concepts.

Several researchers have reported the positive effects of using PBL. Duschl et al., (2008) and Lehrer and Schauble (2006) observed PBL to be especially useful for science education. Other researchers showed that PBL increased problem solving abilities (Cinaglia, 2002; De Simone, 2009; Logerwell, 2009; Lou, Shih, Diez, & Tseng, 2011; Park Rogers & Abell, 2008; Pease & Kuhn, 2010; Schwartz et al., 1999). Lou et al., (2011) noted PBL increased attitudes toward science, technology, engineering, and mathematics subjects. Watters and Ginns (2000) indicated that PBL increased an aspect of self-efficacy and "students' perceptions of the value and importance of science" (p.14).

Self-efficacy is the perception of one's ability to accomplish a task. If a teacher feels they are unable to make a difference in students' outcomes in science, they may decide not to teach the subject. Bandura (1997) states,

> A capability is only as good as its execution. The self-assurance with which people
>
> approach and manage difficult tasks determines whether they make good or poor use of
>
> their capabilities. Insidious self-doubts can easily overrule the best of skills. (p.35)

Further, Bandura (1997) suggests that we only undertake a task if we believe the outcome will be favorable (outcome expectation) and if we believe we can perform the task successfully (self-efficacy). Fear that the outcome will be less than favorable and lack of confidence are what often prevents elementary teachers from teaching science in the classroom.

Self-efficacy has a strong effect on elementary teachers' science teaching practices, and subsequently on student achievement. Carter and Sottile (2002) posited, "self-efficacy is perhaps the key to developing effective teachers" (p.16). Teachers who have low science teaching efficacy beliefs are unlikely to teach science in their classrooms and subsequently affect student achievement in science. Jones and Carter (2007) noted, "although teacher attitudes and beliefs are key to understanding and reforming science education, these areas are poorly understood. Research that can unravel the complexities of teacher attitudes and belief systems is needed" (p.1067). Logerwell (2009) and Watters and Ginns (2000) observed that PBL increased self-efficacy in science teaching. Although studies have evaluated the effects of PBL on elementary preservice teachers' science teaching efficacy beliefs, most studies focused on PBL as a whole. Research on the components of PBL is lacking, especially on the effects of differing amounts of structure in PBL, and the relationship of structure to science teaching efficacy beliefs of elementary preservice teachers.

Hmelo-Silver, Duncan, and Chinn (2007) asked the question, "How much guidance [do] students need in problem based learning?" While some researchers found high structure to be beneficial to students learning, Wijnia, Loyens, and Derous (2011) reported that too much control either by a teacher or by the PBL procedures stifled student motivation and self-regulation. The constructivist learning theory would suggest that students need to be in control of the own learning. Pease (2009) stated,

> In the gathering and sharing information phase of PBL, it remains to be studied the extent
> to which students need a structured process, scripted by the instructor or, if in contrast,
> PBL benefits are the same with students having less structure and more freedom to
> acquire and share the information that allows solving the problem. (pp. 83-84)

Structured resources that provide hints to solving the problem and enabling the student to monitor their progress is one way to assist students while still maintaining student ownership of the problem (Choo, Rotgans, Yew, & Schmidt, 2011; Merriënboer, 1997).

## Purpose of the Study

The purpose of this study was twofold. First, the study examined the effects of differing amounts of structure within the problem based learning instructional model (PBL) on elementary preservice teachers' science teaching efficacy beliefs. Second, the study examined the effects of differing amounts of structure within PBL on content knowledge acquisition. This study contributes to the overall knowledge of the constructivist learning theory, PBL, and its structures, science teaching efficacy beliefs of elementary preservice teachers, and to current teaching and learning practices.

## Statement of the Problem

Elementary preservice teachers' science teaching efficacy beliefs are a vital component in elementary science teaching. Elementary teachers are critical to the science education of children since this is the time in the child's life when they form opinions about science and decide whether to study science, or later in life, to pursue a career in science. Elementary teachers' science teaching efficacy beliefs contribute greatly to the teachers' success and willingness to teach science in the elementary classroom. Problem based learning has been shown to be an important teaching model to develop science content and self-efficacy. However, research was not discovered that looked at optimum structure in the PBL environment. Whether an optimum level of structure in PBL exists, that would maximize science teaching efficacy beliefs in elementary preservice teachers, would be an important discovery.

"Elementary teachers are expected to develop and implement science activities that

engage students in science processes and build on students' natural curiosity and common sense knowledge" (Schwartz et al., 1999, p. 3). However, research consistently demonstrates that elementary teachers feel underqualified; and lack confidence to teach science. This would suggest, "preservice science education courses must have a greater impact on the development of teachers' beliefs about their ability to teach science" (Ginns & Watters, 1999, p. 309).

## Research Questions

Research suggests elementary preservice teachers have low science teaching efficacy beliefs. They are not confident in teaching science, have few science experiences, generally feel underqualified, and are underprepared in science content knowledge and scientific process skills needed for teaching elementary science. These characteristics limit the quantity and quality of science teaching in elementary classrooms. Problem based learning favors authentic experiences that have been shown to increase self-efficacy (Watters & Ginns, 2000). However, little research has addressed structure in PBL in relation to science teaching efficacy beliefs of elementary preservice teachers. For this reason, the purpose of this study was to examine the effects of differing amounts of structure within PBL on elementary preservice teachers' science teaching efficacy beliefs and content knowledge acquisition. More specifically, the study addressed the following two research questions, which include two subscale questions.

1. How did science teaching efficacy beliefs (STEB) change as the result of quantity of structure in a PBL environment?
    a. How did science teaching outcome expectancy (STOE) change as the result of quantity of structure in a PBL environment?
    b. How did personal science teaching efficacy (PSTE) change as the result of quantity of structure in PBL environment?

2. How did science content knowledge differ between groups as the result of quantity of structure in a PBL environment?

## Significance of the Study

The literature on the problem based learning instructional model and science teaching efficacy beliefs expressed an overall positive relationship; however, it was undetermined as to the degree to which the quantity of structure in PBL influenced science teaching efficacy beliefs or science content knowledge. The rationale of this study was to improve science education in elementary preservice teachers by determining whether quantity of structure within the problem based learning instructional model influenced science teaching efficacy beliefs and science content knowledge.

This study contributes to existing literature on the effects of structure in PBL, and leads to a greater understanding of structure in a PBL lesson and its impact on elementary preservice teachers' science teaching efficacy beliefs. Research has shown problem based learning increases student interest in learning and performance in science. The extent to which structured PBL affects science teaching efficacy beliefs and science content knowledge is important to teacher education programs. It provides teacher educators and instructional designers with a better understanding of the role of structure in PBL environments to affect science teaching efficacy beliefs. Hopefully, through such understanding, future elementary teachers will have a better understanding of scientific concepts and processes, and will feel passionate about and qualified to teach science to elementary students.

## Limitations of the Study

This study was a quasi-experimental nonequivalent groups design which had several inherent limitations that needed to be addressed.

1. Due to the natural setting of the classroom, the researcher was unable to control all possible variables. The researcher accounted for alternative explanations that could not be controlled beforehand and assessed whether they were affecting the results of the study as discussed by Shadish, Cook, and Campbell (2001). For example, the time participants spent on each task was controlled by limiting study time to the confines of the normal classroom schedule. A second example involves the participants sharing knowledge of the treatments during other classes they shared. To limit this information sharing between treatment groups, resources were collected at the end of each class by the tutor and held until the next lesson.

2. A convenient (intact) sample was used in this study; therefore, the results cannot be generalized to the general population due to the internal validity threat of selection.

3. Surveys are dependent upon "direct communication with persons….who are reactive in nature", therefore, they may "produce responses that are artificial or slanted" (Isaac & Michael, 1995, p. 137).

4. Participants' prior science background and science content knowledge may influence the science teaching efficacy beliefs examined in this study.

5. The participants of interest in this study were elementary preservice teachers from a midwestern university. Results cannot be generalized to the entire population of teachers.

## Delimitations of the Study

Within the scope of the study, the following delimitations have been established.

1. The variables of interest in this study were science teaching efficacy beliefs, which include two subscales, personal science teaching efficacy, and science teaching outcome expectancy.

2.  This study used the Science Teaching Efficacy Belief Instrument - Preservice (STEBI-B), developed by Enochs and Riggs (1990) and modified by (Bleicher (2004), (Appendix A). Results cannot be compared to studies that use other self-efficacy instruments.

3.  This study implemented PBL as defined by Barrows (1996); therefore, this study cannot  be compared to studies that did not use PBL as so defined.

**CHAPTER 2**

**REVIEW OF LITERATURE**

**Introduction**

This chapter provides a review of the literature relevant to elementary preservice teachers' science teaching. A brief history of the concept of efficacy and science teaching efficacy beliefs in teacher education is provided. The historical background is followed by a description of the benefits of using the problem based learning instruction model (PBL), especially as it relates to science education and science teaching efficacy beliefs. The next section discusses structure and the quantity of structure most beneficial to science teaching efficacy beliefs and science content knowledge acquisition. Finally, this review describes characteristics of elementary science teachers and potential use for PBL in teacher education programs.

**Efficacy**

Efficacy has a strong effect on elementary teachers' science teaching practices, and subsequently on student achievement. Teachers who have low science teaching efficacy beliefs are unlikely to teach science in their classrooms, and subsequently, affect student achievement in science. Bandura (1997) wrote,

> People with a strong sense of self-efficacy view challenging problems as tasks to be mastered, develop deeper interest in the activities in which they participate, form a stronger sense of commitment to their interests and activities, and recover quickly from setbacks and disappointments. Whereas, those who have a weak sense of self-efficacy avoid challenging tasks, believe that difficult tasks and situations are beyond their capabilities, focus on personal failings and negative outcomes, and quickly lose

confidence in personal abilities.  (p. 87)

## Problem Based Learning

**Benefits of Problem Based Learning**

Many researchers have discovered the benefits of the problem based learning instructional model (PBL).  Duschl et al., (2008) and Lehrer and Schauble (2006) found PBL to be especially useful for science education.  The problem based learning instructional model provides authentic experiences that have many benefits both to students and to teachers.  One of the most important benefits for teachers is an increase in self-efficacy.  Watters and Ginns (2000) found that student centered instructional strategies such as PBL have a positive impact on personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). Logerwell (2009) found PSTE and STOE to be positively affected by PBL.  Additionally, PBL improved general science teaching efficacy, general science knowledge, and understanding the nature of science (Logerwell, 2009). The problem based learning instructional model also improved science and math content knowledge (Lou et al., 2011).

Additional studies looked at how students may be influenced by PBL.  These findings indicate the importance of PBL and its use to encourage young people to study science.  An increase was found  in "students' perceptions of the value and importance of science" (Watters & Ginns, 2000), attitudes toward science, technology, engineering, and mathematics (STEM) integrated learning, future career choices in STEM (Lou et al., 2010), and problem solving abilities (Cinaglia, 2002; De Simone, 2009; Logerwell, 2009; Lou et al., 2010; Park Rogers & Abell, 2008; Pease & Kuhn, 2010; Schwartz et al., 1999). Watters & Ginns (2000) indicated a need to implement science programs that use an inquiry based approach, such as PBL.

**Structure in Problem Based Learning**

Just as in the case of the scaffolding around a building, there is a facilitative structure of supports and boards (temporal and changeable, which the workers need to carry out their work), and there is the actual work that is being carried out….In pedagogical contexts, scaffolding has come to refer to both aspects of the construction site: the supportive structure (which is relatively stable, though easy to assemble and reassemble) and the collaborative construction work that is carried out….Most importantly, then, the dynamics between the scaffolding structure and the scaffolding process must be kept in mind. The process is enabled by the scaffolding structure, and a constant evaluation of the process indicates when parts of the scaffolding structure can be dismantled or shifted elsewhere. (Walqui, 2006, p. 164)

Merriënboer (1997) defines scaffolding as "problem-solving support or procedure support that is integrated with practice and decreases as the learners gain more experience. Particular problem formats, problem sequences, process worksheets, constraints on performance, or cognitive tools may be used to scaffold a learner" (p. 321). Saye and Brush (2002) further describe two types of scaffolding called hard scaffolds and soft scaffolds. "Hard scaffolds are static supports that can be anticipated and planned in advance based on typical student difficulties with a task" (Saye & Brush, 2002, p. 81). Examples of hard scaffolds include "computer or paper-based cognitive tools, e.g. worksheets" (Belland, Glazewski, & Richardson, 2008); "process worksheets" (Merriënboer, 1997); and resources which "provide hints or descriptions of the phases one should go through when solving the problem", (Choo et al., 2011, p. 519).

"Soft scaffolds are dynamic and situational.  Soft scaffolding requires teachers to continuously diagnose the understandings of learners and provide timely support based on student responses" (Saye & Brush, 2002, p. 82).  Saye and Brush (2002) describe soft scaffolds as teacher actions in response to learners' specific needs.  Closely related to teachers are expert tutors who work closely with students and facilitate the process of PBL.  Problem based learning often uses a whiteboard and worksheets, which are seen as hard scaffolds.  "The whiteboard helps students externalize their problem solving and allows them to focus on more difficult aspects of the problem-solving process.  It provides a model of a systematic approach to problem solving and supports student planning and monitoring as they identify what needs to be recorded on or later removed from the board" (Hmelo-Silver, 2004, p. 242).  "Information that may be helpful to performance of the whole task is provided in such a way that it is easily retrievable, accessible, and available during practice" (Merriënboer, 1997, p. 76).  Structured "worksheets may be provided to the learners to support them in the use of a systematic approach to problem solving, or 'cognitive tools' may be developed inviting the learners to apply useful heuristic problem solving support" (Merriënboer, 1997, p. 166).

"The more open the problem is to interpretation, the more ill-structured the problem will be.  How a problem solver interprets the problem (initial state) will naturally lead to diverse and sometimes conflicting interpretations about the goal state of the problem, the necessary operators, and the constraints that restrict or regulate the operators" (Jonassen & Hung, 2008,  p. 13).  The less structured the problem the more students will be open to provide his or her own interpretation of problem goals.  This leads to greater diversity in outcomes.  The greater the structure the more confinement and restriction of outcomes and content knowledge acquisition.

## Structure and Constructivism

Hmelo-Silver et al., (2007) questioned the amount of guidance students needed in PBL. Problem authenticity is useful as a motivator for learning. However, the use of more guidance in the forms of whiteboards, worksheets, or collaborative problem solving groups could jeopardize this authenticity. Choo et al., (2011) noted,

> By integrating hard scaffolds such as worksheets into the PBL curriculum, this may reduce students' feeling of choice and autonomy, which leads to less engagement and learning. Since students in a PBL environment are expected to engage in their own knowledge construction to solve the problem, there could be a possibility that worksheets and PBL are not reconcilable. As worksheets tend to impose the theories on the students, this may affect the process of the students' knowledge construction. However, this is only a tentative explanation, as more research is needed to establish the link between autonomy reduction and hard scaffolds in PBL. (p. 525)

Merriënboer (1997) noted, "Scaffolding often makes the task less authentic" (p. 187). "When a behavior is self-determined, the regulatory process is choice, but when it is controlled, the regulatory process is compliance (or in some cases defiance)" (Deci, Vallerand, Pelletier, & Ryan, 1991, p. 327).

> Pease (2009) found,

> In the gathering and sharing information phase of PBL, it remains to be studied the extent to which students need a structured process, scripted by the instructor or, if in contrast, PBL benefits are the same with students having less structure and more freedom to acquire and share the information that allows solving the problem. (p. 83-84)

> "The use of scaffolds in general and [in a] PBL context has demonstrated varying

degrees of impact on student learning achievements" (Choo et al., 2011, p. 519).

Schmidt (1994) found,

> The higher the level of structure of the unit, the better the achievement. Students
> need a minimum level of structure in order to profit from problem based
> instruction. This structure can be internally provided through prior knowledge
> available for understanding the new subjects, or offered by the environment in the
> form of cues of what is relevant and what should be the focus of the activities. If
> prior knowledge falls short, or if the environment lacks structure, students will
> turn to their tutors for help and direction. Under those conditions, students who
> are guided by a subject-matter expert tutor may benefit more than students who
> are guided by a non-expert staff tutor or by a student tutor. These findings may
> explain the widely divergent results of tutor expertise research. (p.656)

Jonassen and Hung (2008) found that, "in order to solve a problem that contains
unknowns in the problem space, the problem solver must solve the problem based on
assumptions or guesswork. These assumptions or guesswork inevitably reduce the problem
solver's confidence level in successfully solving a problem" (pp. 11-12). Additionally, Choo et
al., (2011) found that "scaffolds such as worksheets may not play a significant role in enhancing
students' learning within the social constructivist framework of problem based learning" (p.
517). Jonassen and Hung (2008) summarized general principles for designing good PBL
problems.

PBL problems should be:

- Open ended, ill structured, however,
    - With a moderate degree of structuredness;

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- Complex, however, the degree of complexity should

  o Be challenging and motivating, engaging students' interests;

  o Provide opportunities for students to examine the problem from multiple perspectives or disciplines;

  o Adapted to students' prior knowledge;

  o Adapted to students' cognitive development and readiness;

- Authentic

  o Contextualized as to students' future or potential workplaces.  (p. 16)

 "Problems that are likely to be most successfully implemented in PBL programs are those that are moderately ill structured (near the median) and slightly above average in complexity" (Jonassen & Hung, 2008, pp. 15–16).  Jacobs, Dolmans, Wolfhagen, and  Scherpbier (2003) found "if a problem was too ill-structured and too complex, the students had difficulty in dealing with it, because it did not fit in with the students' level of prior knowledge (p. 6)."   Structured worksheets that provide hints to solving the problem and enabling the student to monitor their progress is one way to assist students while still maintaining student ownership of the problem (Choo et al., 2011; Merrienboer, 1997).  However, Wijnia et al., (2011) found that too much control either by a teacher or by the PBL procedures stifled student motivation and self-regulation.  Additionally, Verkoeijen, Rikers, Winkel, and Van den Hurk (2006) found that "the use of goal-free problems [had] a positive effect on the students' individual study and the extensiveness of the tutorial group meeting" (p. 337).  Verkoeijen, et al., (2006) compared a goal-specified problem scenario with goal-free condition and found that the goal-free condition resulted in the students reading more articles, studying longer, and spending more time

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discussing the literature.  Therefore, Verkoeijen et al., (2006) recommended using goal-free problems in PBL courses in order to improve quality and quantity of students' individual study.

"The positive results on scaffolding-related learning could inform and influence how teacher educators and teachers conceptualize the dynamics of science teaching" (Lin et al., 2012, p. 444).  The researchers suggest that "design, application, and management of scaffolding are essential components of pedagogical content knowledge for teaching in science classrooms" (p. 444).  "The focus should shift from researching effectiveness of PBL versus traditional learning, and should refocus on studying the differences in effectiveness of support structures to find optimal scaffolding, coaching, and modeling strategies for successful facilitation of PBL" (Strobel & van Barneveld, 2009, p. 55).  "It remains a matter for further research to investigate the possibility of correlations between structure and success … and what possibilities exist for establishing such scaffolding without threatening the essential nature of PBL" (Greening, 1998, p. 8).  "Educators are discovering the delicate balance between appropriate scaffolding within constructivist pedagogues" (Greening, 1998, p.9).

### Characteristics of Elementary Science Teachers

Studies show elementary teachers are lacking adequate science content knowledge, which leads to ineffective science teaching.  For example, Dobey and Schafer (as cited in Gess-Newsome, 1999) stated,  "content knowledge is often the limiting factor to effective science instruction." In addition, Schwartz et al., (as cited in Gess-Newsome, 1999), state that teachers' level of content knowledge positively correlates with student outcomes on standardized tests of science.  "To make matters worse, science is often the teacher's greatest weakness" (Friedl, 1997, p. 2).  Weiss (1994) found that over two thirds of elementary teachers feel unqualified to teach science.  Abell and Roth (1991) also noted that teachers felt unqualified or uncomfortable

with the idea of teaching science.  The Australian Science, Technology, and Engineering Council (1997) indicated that both inexperienced and experienced teachers said they were not confident teaching science.  Hanson and Akerson (2006) stated, "elementary teachers lack confidence with science content and have low science teaching efficacy".

Teaching science at the elementary level requires content and pedagogical knowledge. "Elementary teachers are expected to develop and implement science activities that engage students in science processes and build on students' natural curiosity and common sense knowledge" (Schwartz et al., 1999, p. 3). However, because they teach all subjects they are limited in the time spent preparing for science teaching.  In addition, Van Aalderen-Smeets et al., (2011) established that "primary school teachers are not adequately trained to teach science" (p. 159).

## Teacher Education

Jarvis, McKeon, and Taylor (2005) concluded that preservice teachers' confidence could be enhanced through a self-regulated learning environment.  Similarly, Taylor & Corrigan (2005) reported that students had more positive attitudes towards science and increased confidence in their ability to teach elementary science after working with investigations in a self-regulated environment.  Ginns and Watters (1999) wrote,

> Preservice science education courses must have a greater impact on the development of teachers' beliefs about their ability to teach science.  Collaborative learning experiences, reflective journal writing, and problem based assignment tasks employed in subsequent offerings of the science education course have been shown to be effective strategies for this purpose.  (p. 306)

In addition, Carter and Sottile (2002) suggested, "positive self-efficacy [would] have a

great impact on the effectiveness of new teachers" (p. 2) and suggested, "self-efficacy was perhaps the key to developing effective teachers" (p.16).

## Summary

In summary, science is not being taught sufficiently in elementary classrooms to meet the science and technological demands of our society. Elementary teachers lack the content knowledge and confidence to develop an interest in science, which would help develop a strong self-efficacy that would result in a change in quantity and quality of elementary science being taught. The problem based learning instructional model was founded within the constructivist learning theory. Research supports its positive impact on science content acquisition and self-efficacy. What remains to be studied is the influence quantity of structure in the problem based learning instructional model has on self-efficacy of elementary preservice science teachers.

## Teacher Education

The literature demonstrates that elementary teachers of science are not properly trained to have a full understanding of science concepts and practices. This is disturbing because science content knowledge is one of the most important aspects for effective science instruction. There are high expectations placed on elementary teachers. They are responsible for preparing and teaching all content areas of the curriculum, limiting preparation time dedicated to science. These conditions lead to teachers having low confidence in their abilities to teach science, a feeling of being unqualified, and to feeling uncomfortable teaching science. Increasing elementary preservice teacher confidence in science teaching, and understanding teacher attitudes and beliefs about science content and its' process is important but poorly understood. A program such as one using the problem based learning instructional model can increase teacher confidence.

**Efficacy**

Positive science teaching efficacy beliefs shows that if one has confidence in their own abilities to teach science there will be positive outcomes. The literature indicated that a strong sense of science teaching efficacy beliefs among elementary preservice teachers is an important component of success in teaching elementary science. Literature indicated teachers should have a strong understanding of scientific ideas and practices and be grounded in basic science content knowledge if science teaching efficacy beliefs are to increase. Increasing elementary preservice teacher confidence and understanding teacher attitudes and beliefs about science content and its' process is important if elementary students are to choose science paths.

**Benefits of Problem Based Learning**

The literature shows that the problem based learning instructional model is effective for both teachers and students at increasing content knowledge and scientific process skills. There are several benefits of PBL for teachers. The literature showed that problem based learning increased science content knowledge including improved science knowledge in biology, chemistry, math and the understanding of nature of science plus science teaching efficacy beliefs. The benefits for students are also numerous. The literature found that PBL increased the perception of value and importance of science, attitudes about science, and its integration with technology, engineering, and math, and stem careers, content knowledge, and problem solving abilities of students.

**Structure in Problem Based Learning**

The literature indicates there is a substantial amount of research on problem based learning and its effects on science content knowledge and science teaching efficacy beliefs among elementary school teachers. However, literature found the components of problem based

learning still needed further study.  Research on quantity of structure was specifically noted as lacking.  There is a need for a study to determine the optimum level of structure in the problem based learning instructional model to increase science teaching efficacy beliefs among elementary preservice teachers.  Within the PBL environment structure can be hard static supports that are prepared ahead of the lesson such as worksheets, software, or other cognitive tools that help the process of problem solving or soft dynamic supports that are timely depending on the needs of the student.  Examples of the latter would be verbal support when the student is struggling, questioning the student to help deepen their thoughts, or recommending resources for further study.

**Constructivism as it Relates to Structure**

The literature cited constructivism as the underlying theory of the problem based learning instructional model.  One of the tenants of the constructivist learning theory is the importance of authenticity.  The literature indicated a debate concerning the amount of structure in PBL that could best improve results.  The literature showed that adding too much structure to PBL left the learner feeling like they had no autonomy thus stifling student motivation and self-regulation and reduced learning.  Goal-free problems had positive effects on students' individual study and extensiveness of tutorial group meetings.  In addition, goal-free problems led to more article reading, longer study sessions, and more time discussing the literature.  However, research also stated that too little structure resulted in the learner solving a problem based on guesswork, which lowered the confidence level of the learner.

<p style="text-align:center"><strong>Directions from Literature Review</strong></p>

A review of the literature revealed that elementary preservice teachers need science content knowledge, an understanding of scientific processes, as well as strong science teaching

efficacy beliefs to be effective science teachers.  Literature indicates the problem based learning instructional model can increase these teacher aspects.  This study examined the use of the problem based learning instructional model by elementary preservice teachers.

The literature indicated that an optimal amount of structure in PBL had not been found. This study compared two levels of structure in the problem based learning instructional model to determine if one level was more effective than the other at increasing science teaching efficacy beliefs and science content knowledge of elementary preservice teachers.

# CHAPTER 3

# RESEARCH METHODOLOGY

## Introduction

Elementary science education is important for the economic and technological development of a scientifically literate society (NRC, 1996). Despite this societal need, research shows that elementary preservice teachers have low science teaching efficacy, are not confident in teaching science, have few science experiences, and generally feel underqualified in teaching science, thus limiting the amount of science taught in elementary classrooms. One solution is to use the problem based learning instructional model (PBL) to provide authentic experiences that have been shown to increase self-efficacy (Watters & Ginns, 2000) and science content knowledge. However, researchers have not determined an optimal amount of structure that will maintain authenticity to gain the best effect on science teaching efficacy beliefs of elementary preservice teachers. This research addressed structure in relation to science teaching efficacy beliefs and science content knowledge acquisition of elementary preservice teachers.

## Research Questions

The purpose of this study was to examine the effects of differing amounts of structure within PBL on elementary preservice teachers' science teaching efficacy beliefs and content knowledge acquisition. More specifically, the study examines the following questions.

1. How did science teaching efficacy beliefs (STEB) change as the result of quantity of structure in a PBL environment?
   a. How did science teaching outcome expectancy (STOE) change as the result of quantity of structure in a PBL environment?

b. How did personal science teaching efficacy (PSTE) change as the result of quantity of structure in PBL environment?

2. How did science content knowledge differ between groups as the result of quantity of structure in a PBL environment?

## Design Construction

This study used a quasi-experimental nonequivalent groups design using a pretest and a posttest, (Table 1). The purpose of using this design was "to approximate the conditions of the true experiment in a setting which does not allow the control and/or manipulation of all relevant variables" (Isaac & Michael, 1995, p. 58). This design is often used with a convenient sample, such as an existing classroom, as was done in this study.

Two groups experienced a PBL lesson with varying degrees of structure. One group experienced a low amount of structure while the other experienced a higher amount of structure. More specifically, one group received core ideas to consider, (Appendix B), and resources for further study, (Appendix C), while the other group did not receive these resources. The independent variable in this study was the amount of structure given to participants during the PBL lesson. There were two dependent variables. The first was the participants' science teaching efficacy belief scores, which consisted of two subscales, the personal science teaching efficacy score and the science teaching outcome expectancy score. The second dependent variable was the participants' demonstrated content knowledge.

Table 1

*Quasi-Experimental Nonequivalent Groups Design*

| | Pretest | | Treatment | Posttest | |
|---|---|---|---|---|---|
| Lower Structured Experimental Group (N) | $O_1$ | $O_2$ | LS | $O_3$ | $O_4$ |
| Higher Structured Experimental Group (N) | $O_1$ | $O_2$ | HS | $O_3$ | $O_4$ |

*Note.* N = Non-randomization; $O_1 =$ STEBI-B Pretest; $O_2 =$ Demographic Questionnaire; LS = Low Structure PBL; HS = High Structure PBL; $O_3 =$ STEBI-B Posttest; $O_4 =$ Interview.

## Research Participants

The participants in the study were 60 undergraduates in an elementary teacher education program at a large midwestern university in a town of 26,000 people in the United States. Students were enrolled in one of two science methods courses, divided among three sections. Nineteen students were enrolled in *Introduction to Elementary School Science* and 41 students were enrolled in *Science Processes and Concepts for Teachers*. The researcher used Microsoft Excel (2007) to randomly assign each class into one of two treatment groups, one with higher structure (n = 38) and one with lower structure (n = 22). The tutor asked the university students to take pretests and posttests, attend three classes (each ninety minutes), participate in a PBL lesson, spend approximately three additional hours researching a problem (Appendix D), and prepare a poster presentation. Both treatment groups received the same problem. The structure was in the form of core ideas to consider and resources for further study. As shown in Table 2, the majority of participants were Caucasian females, in their early 20's and juniors or seniors in a four-year elementary education program. Most participants (78%) reported having had positive experiences and feelings toward science. Forty eight percent (48%) were planning to specialize in science or math. The participants overall had taken a high number of science classes while in

high school and college.

Table 2

*Background Characteristics of Research Participants (N=60)*

| Category | N | % |
| --- | --- | --- |
| Gender | | |
| Female | 51 | 85 |
| Male | 9 | 15 |
| Ethnicity | | |
| Caucasian | 55 | 92 |
| Hispanic | 1 | 2 |
| Other (Not Reported) | 4 | 6 |
| Age | | |
| 20-22 | 42 | 70 |
| 23-25 | 10 | 17 |
| 26-30 | 5 | 8 |
| 31-45 | 3 | 5 |
| Years of College | | |
| 0-4 | 45 | 75 |
| 5-10 | 14 | 23 |
| 10+ | 1 | 2 |
| Major | | |
| Elementary Education | 48 | 80 |
| Special Education | 1 | 2 |
| Dual El Ed and Sp Ed | 11 | 18 |
| Specialty | | |
| Science | 18 | 30 |
| Math | 11 | 18 |
| Other | 22 | 37 |
| Not Reported | 9 | 15 |
| Number of Degrees Earned | | |
| 0 | 33 | 55 |
| 1 | 20 | 33 |
| 2-3 | 7 | 12 |
| High School Science Courses | | |
| 0-2 | 12 | 20 |
| 3-4 | 44 | 73 |
| 5-8 | 4 | 7 |
| College Science Courses | | |
| 0-2 | 1 | 2 |
| 3-5 | 38 | 63 |
| 6-8 | 18 | 30 |
| 9+ | 3 | 5 |
| Science Experience | | |
| Positive | 47 | 78 |
| Negative | 13 | 22 |

**Access and Recruitment of Participants**

The researcher asked and received approval from the professors of the science methods courses for access to the preservice teachers in their classes during their normal class times as participants in this study. The researcher applied to the human subjects committee in the Office of Sponsored Projects Administration (OSPA) to use human subjects and was approved before any data were collected. The researcher then presented the participants an invitation to join the study. The researcher informed the participants, through a consent form (Appendix G), of the purpose of the study, the data to be collected, and of the confidentiality of their data. Participants were informed that participation or non-participation in the study would have no effect on their grade in their class.

## Tutor

Schmidt (1994) indicated that students benefited by being led by expert tutors during problem based learning. The tutor for this study had advanced degrees in biology and curriculum and instruction and had over 30 years of teaching experience. He had experience teaching college and university students in the areas of general biology, environmental biology, marine biology, and curriculum and instruction. These qualifications indicate the tutor was highly qualified in the area of the problem the students would try to solve and could be considered an expert tutor.

Research indicated tutor training was necessary (Leary, Walker, Fitt, & Shelton, 2009) for an effective PBL lesson. Tutor training involved the study of materials, including books, articles, and videos designed to instruct K-12 teachers and university professors of the planning and implementation of PBL in the classroom. Materials by Hmelo-Silver and Barrows (2006) and Barrows (1986) were used to ensure Barrow's definition of PBL was adhered to in the study.

In addition, neutral guiding questions, developed by the researcher, were used by the tutor in an effort to give both treatment groups the same type responses or prompts (Appendix H).

## Data Collection Instruments

Participants responded to three instruments: science teaching efficacy belief instrument - preservice (STEBI-B), developed by Enochs and Riggs (1990) and modified by Bleicher (2004), a demographic questionnaire, and a structured interview (Appendices A, I,& J).

### Science Teaching Efficacy Belief Instrument – Preservice (STEBI-B)

The elementary preservice teachers' science teaching efficacy belief scores, including personal science teaching efficacy and science teaching outcome expectancy, were measured using the science teaching efficacy belief instrument - preservice (STEBI-B), developed by Enochs and Riggs (1990) and modified by Bleicher (2004) (Appendix A). The modified STEBI-B consists of two subscales that measure personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). Together they contain 23 items the participants rated as either *"strongly agree", "agree", "uncertain", "disagree"* or *"strongly disagree".* The modified STEBI-B scale item explanations are found in Appendix K.

The modified STEBI-B is a valid and reliable instrument, used by many researchers, to measure science teaching efficacy beliefs of elementary preservice teachers. "A factor analysis established that the two subscales, personal science teaching efficacy belief (PSTE) and science teaching outcome expectancy (STOE), on the STEBI-B were homogeneous" (Bleicher, 2004, p. 383). Reliability coefficient for PSTE beliefs scale was 0.87. Reliability coefficient for STOE beliefs scale was 0.72. The modified STEBI-B reliability scores are found in Appendix L. The request to use the modified STEBI-B is found in Appendix M, and the document giving the researcher permission to use the STEBI-B is found in Appendix N.

**Demographic Data Questionnaire**

Demographic data were collected, using an instrument designed by the researcher. The data collected included age, gender, ethnicity, years of college, college major, specialty area, number of degrees earned, number and type of high school science courses, and number and type of college science courses. It also asked participants to indicate their general feelings about past science experiences (Appendix I).

**Structured Interview Protocol**

The researcher developed a structured interview protocol (Appendix J) to provide qualitative verification of quantitative data. Twelve students, six from each treatment group, were randomly selected using Microsoft Excel (2007) and interviewed after the study. Sample questions included, "Did you feel you had the resources you needed to solve the problem?" and "What other resources do you wish you had?" Expected answers were related to amount of information, type of information, amount of time, amount of support from the tutor, or internet resources.

<div align="center">

**Data Collection Procedures**

</div>

Participants were asked to volunteer for the study and were given a consent form to sign (Appendix G). They were informed that their data would be kept confidential and would in no way affect their grade for the course. The tutor collected data on the first and last days of the study. On the first day, the participants were given consent forms, the STEBI-B pretest (Appendix A), and a demographic questionnaire (Appendix I). The tutor discussed the forthcoming days' lessons, the assignments, and the problem based learning instructional model. The groups divided themselves into research teams of 4 or 5 persons each. Next, the tutor gave the participants a copy of the problem (Appendix D), a modified KWL (what do you *know*, what

do you *want* to know, what do you want to *learn*) worksheet for note taking as shown in Appendix P, and the rubric (Appendix O) to be used for the final poster presentation assignment. In addition, the higher structured groups received core ideas to consider (Appendix B) and suggested resources for further research (Appendix C) while studying the PBL problem (Appendix D). To maintain fidelity of treatment the tutor was provided a PBL lesson plan (Appendix Q).

The tutor read the PBL problem aloud to the participants and worked through the K (what do you know) section of the KWL chart with the participants. The tutor used large poster paper, attached to the wall, to record participants' responses. The poster paper enabled students to study past responses and to formulate new understanding and connections (Barrows, 1997). Next, the participants, guided by the tutor, worked through the W (what do you want to know) section of the KWL chart, and finally, worked through the L (what do you need to learn and do) section of the chart. This final section helped the participants determine what each participant would research outside of class. On the second day of the study, participants shared their research findings within and between teams. They also were given an opportunity to modify previous class responses. Further research was conducted in class (on computers and information sheets brought in from participant research). Participants clarified solutions to the problem and allocated poster presentation responsibilities. On the third and final day of the study, participants finalized and presented their posters to the class. In addition, they took a STEBI-B posttest. A structured interview was given two weeks after the end of the study. Six participants from each group were randomly selected to meet with the researcher. The interviews took place over three days in three groups. Each interview lasted approximately 30 minutes.

The researcher designed an analytic rubric (Appendix O), to evaluate group presentations. The rubric measured participants' understanding of the problem, utilization of research, choice of solutions, resources, organization, and demonstrated content knowledge.

**Data Analysis**

The modified science teaching efficacy belief instrument-preservice (STEBI-B) was used to collect data from all participants. The researcher collected pretest and posttest data to determine the elementary preservice teachers' changes in science teaching efficacy beliefs scores, which included personal science teaching efficacy scores and science teaching outcome expectancy scores. An analysis of covariance (ANCOVA) determined whether the scores between groups differed. An assumption of homogeneity test and an ANCOVA test were run for each of the three dependent variables, STEB, PSTE, and STOE. Analysis of covariance was chosen because the design of the study was a quasi-experimental nonequivalent groups design. The tutor scored the instruments according to Bleicher (2004) (Appendix K). The researcher calculated Cronbach's alpha for pretest and posttest scores to determine reliability. Follow up paired samples *t*-tests of pretest and posttests of all participants were conducted to determine if there was a change in science teaching efficacy belief scores unrelated to structure. Independent samples t-tests were performed on the poster rubric scores to determine content knowledge acquisition differences between groups. Intraclass correlation coefficient (ICC) was used to determine interrater reliability between the poster presentation raters. Cohen's *d* was used to determine the effect size for the results of the science content knowledge scores. Tests were performed using IBM Statistical Package for the Social Sciences (SPSS) version 21.

**Reliability and Validity**

The naturalistic design of the study added validity, but also limited the researcher's

control.  Social threats to internal validity are due to natural reactions participants have to the world around them.  For example, a person's impression of the researcher could potentially influence a participant's responses (Isaac & Michael, 1995).  This is known as The Halo Effect, which states that irrelevant information can influence ratings on all future observations.

This study tried to limit possible confounding variables.

- One tutor led all three groups, thus limiting variation in tutor personality, time on task, and quality of content.

- A PBL lesson plan was provided to the tutor to ensure the tutor followed the PBL protocol treatment (Appendix Q).

- Tutor protocols (Appendix R) were developed by the researcher to ensure the tutor adhered to the steps found in PBL, as defined by Barrows (1997).

- An instrument was developed by the researcher to ensure fidelity of treatment between groups (Appendix S).  The instrument was adapted from Delisle (1997) and van Berkel, Scherpbier, Hillen, & van der Vleuten (2010).

- Fidelity raters scored each lesson to ensure treatment between groups was consistent. Raters were three graduate students and a professor in the department of Curriculum and Instruction.

- The poster presentation raters used a analytic rubric, designed by the researcher, to evaluate the participants' understanding of the problem, utilization of research, choice of solutions, resources, organization, and demonstrated content knowledge  (Appendix O).

-  Intraclass correlation coefficient was calculated to determine interrater reliability.

## CHAPTER 4

## RESULTS

### Introduction

The purpose of this study was to examine effects of differing amounts of structure within PBL on elementary preservice teachers' science teaching efficacy beliefs (STEB) and content knowledge acquisition. Specifically, there were two research questions.

1. How did science teaching efficacy beliefs change as the result of quantity of structure in a PBL environment?

   a. How did science teaching outcome expectancy change as the result of quantity of structure in a PBL environment?

   b. How did personal science teaching efficacy change as the result of quantity of structure in PBL environment?

2. How did science content knowledge differ between groups as the result of quantity of structure in a PBL environment?

This chapter describes the results of the analyses of the quantitative and qualitative measures that address the research questions. Analyses included Cronbach's alpha, intraclass correlation coefficient (ICC), independent samples *t*-test, paired samples t-test, and three assumptions of homogeneity and analyses of covariance (ANCOVA). Tests were performed using IBM SPSS 21. Sixty students were sampled, $N = 60$.

### Reliability

**Internal Consistency Reliability**

The researcher entered responses from the 60 participants into IBM SPSS version 21.0. Reliability tests were run for the pretests and posttests of the modified science teaching efficacy

beliefs instrument – preservice (STEBI-B).  Reliability tests examined item means of this study

compared with those from Bleicher's (2004) study (Table 3).  The item means for the data from

the current study were consistently higher than those for Bleicher (2004).  The researcher

speculates causes for this effect.  One difference between the two studies is the age of the

participants.  In this study, 70% of participants were under 22 years of age, while in Bleicher'

study, only 32% of participants were under the age of 22.  The younger students in the study may

have had more recent experiences with science and inquiry based experiences, resulting in a

higher self-efficacy score.  Another explanation is that younger students may not know what they

do not know; resulting in a higher self-efficacy.  Another consideration is that of sample size.

Bleicher's study had a sample size of 290 while (Sasser (2014) had a relatively small sample of

60.

George and Mallery (2011) reported that Cronbach's alpha coefficients from .60 to .79

indicate moderate reliability while coefficients from .80 to .89 are considered good reliability.

The research instrument used in this study, STEBI-B, and its subscales had moderate to good

reliability (Table 4).  One of the pretests (PSTE) had good internal consistency (.87), while the

other two (STEB and STOE) had moderate internal consistency with .75 and .73, respectively.

All three posttests had good internal consistency, STEB, .81; STOE, .82; and PSTE, .88.

Table 3

*Comparison of Item Means and Standard Deviations of STEBI-B Between this study and Bleicher (2004)*

| Item Number | Sasser (2014) (N=60) | | Bleicher (2004) (N=290) | |
|---|---|---|---|---|
| | Standard Deviation | Mean | Mean | Standard Deviation |
| 1 | 0.87 | 4.02 | 3.77 | 0.97 |
| 2 | 0.65 | 4.70 | 4.48 | 0.57 |
| 3 | 0.88 | 3.93 | 3.78 | 0.98 |
| 4 | 0.74 | 4.03 | 4.16 | 0.70 |
| 5 | 0.83 | 3.83 | 2.33 | 0.86 |
| 6 | 0.72 | 4.22 | 3.82 | 0.81 |
| 7 | 0.96 | 3.58 | 3.31 | 1.01 |
| 8 | 1.00 | 4.08 | 4.14 | 0.74 |
| 9 | 0.62 | 4.18 | 4.14 | 0.74 |
| 10 | 0.82 | 3.27 | 2.76 | 0.92 |
| 11 | 0.69 | 3.85 | 3.68 | 0.85 |
| 12 | 0.90 | 3.88 | 2.88 | 0.96 |
| 13 | 0.72 | 4.08 | 3.43 | 0.99 |
| 14 | 0.88 | 3.67 | 3.63 | 0.84 |
| 15 | 0.73 | 3.80 | 3.62 | 0.91 |
| 16 | 0.73 | 3.75 | 3.71 | 0.84 |
| 17 | 0.77 | 4.02 | 3.49 | 0.84 |
| 18 | 0.62 | 3.95 | 3.39 | 0.84 |
| 19 | 0.99 | 3.50 | 2.87 | 1.06 |
| 20 | 1.21 | 3.47 | 3.47 | 0.96 |
| 21 | 0.69 | 4.12 | 3.78 | 0.84 |
| 22 | 0.65 | 4.50 | 4.37 | 0.70 |
| 23 | 0.76 | 4.07 | 3.26 | 1.02 |

Table 4

*Reliability Test Statistics for the Modified Science Teaching Efficacy Beliefs Instrument*

|  | Research Instruments | Number of items | Cronbach's Alpha |
|---|---|---|---|
| Pretest | STEB | 23 | .748 |
|  | STOE | 13 | .733 |
|  | PSTE | 10 | .870 |
| Posttest | STEB | 23 | .812 |
|  | STOE | 13 | .817 |
|  | PSTE | 10 | .881 |

*Note*. STEB = Science Teaching Efficacy Beliefs; STOE = Science Teaching Outcome Expectancy; PSTE = Personal Science Teaching Efficacy

**Interrater Reliability**

Interrater reliability was calculated for the science content knowledge variable.  Interrater reliability is used to assess the degree to which different raters "make consistent estimates of the same phenomenon" (Multon, 2010, p. 627).  According to Leech, Barrett, & Morgan (2011), this type of reliability is needed when scoring involves some degree of subjective judgment. Two raters, each with over 30 years of science teaching experience, individually scored participants posters as to the amount of content knowledge expressed.  The raters evaluated 14 poster presentation teams.  Raters and participants were not randomly selected; therefore, interrater reliability could be assessed using a two-way mixed model.  It was appropriate to use consistency and average-measures intraclass correlation coefficient (ICC) since the means of the rater scores were used for data analyses (Hallgren, 2012).  According to cut-off values provided

by Cicchetti (1994), the resulting two-way mixed, consistency, average-measures ICC indicated good (.60 -.74) agreement, *ICC* = .698.

## Research Questions

**Research Question 1: How did science teaching efficacy beliefs (STEB) change as the result of quantity of structure in a problem based learning environment?**

A one-way analysis of covariance (ANCOVA) was conducted for this question. The independent variable, structure, included two levels: low amount of structure and high amount of structure. The dependent variable was the students' STEB and the covariate was the students' score on the STEB pretest. A preliminary analysis evaluating the homogeneity-of-slopes assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(1, 56) = .50$, $MSE = 31.80$, $\rho = .483$, partial eta squared = .009. The results of this test indicated the assumption of the ANCOVA had been met, thus, it was acceptable to run the ANCOVA for this data.

Table 5 shows the ANCOVA was not significant, $F(1, 57) = .63$, $MSE = 31.52$, $\rho = .429$, partial eta squared = .011. The strength of the relationship between the independent variable and the dependent variable was small, as assessed by the partial eta squared, with low structure accounting for 1% of the variance of the dependent variable, accounting for pretest scores. The STEB of the two groups did not differ significantly regardless of the amount of structure present in PBL.

Table 5

*Analysis of Co-Variance for Science Teaching Efficacy Beliefs (STEB) by Amount of Structure*

| Source | SS | df | MS | F | $\rho$ | $\eta^2$ |
|---|---|---|---|---|---|---|
| STEB Pretest | 1,952.22 | 1 | 1952.22 | 61.94 | .000 | .521 |
| Structure | 19.98 | 1 | 19.98 | .63 | .429 | .011 |
| Error | 1,796.41 | 57 | 31.52 | | | |
| Total | 495,422.00 | 60 | | | | |

**Research Question 1a:  How did science teaching outcome expectancy (STOE) beliefs change as the result of quantity of structure in a problem based learning environment?**

A one-way analysis of covariance (ANCOVA) was conducted.  The independent variable, structure, included two levels: lower amount of structure and higher amount of structure.  The dependent variable was the STOE beliefs and the covariate was the STOE pretest. A preliminary analysis evaluating the homogeneity-of-slopes assumption indicated the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(1, 56) = 1.48$, $MSE = 15.67$, $\rho = .229$, partial eta squared = .026.  The results of this test indicated the assumption of the ANCOVA had been met, thus, it is acceptable to run the ANCOVA for this data.

The ANCOVA was not significant, $F (1, 57) = .02$, $MSE = 15.80$, $\rho = .880$, partial eta squared = .000.  The strength of the relationship between the independent variable and the dependent variable, STOE, was small, as assessed by the partial eta squared with structure accounting for less than 1% of the variance of the dependent variable, accounting for pretest

scores.  The STOE beliefs of the two groups did not differ significantly due to the amount of

structure present in PBL (Table 6).

Table 6

*Analysis of Co-Variance for Science Teaching Outcome Expectancy (STOE) by Amount of*
*Structure*

| Source | SS | df | MS | F | $\rho$ | $\eta^2$ |
|---|---|---|---|---|---|---|
| STOE Pretest | 456.33 | 1 | 456.33 | 28.89 | .000 | .336 |
| Structure | .37 | 1 | .37 | .02 | .880 | .000 |
| Error | 900.41 | 57 | 15.80 | | | |
| Total | 89,070.00 | 60 | | | | |

**Research Question 1b:  How did personal science teaching efficacy (PSTE) beliefs change**

**as the result of quantity of structure in a problem based learning environment?**

A one-way analysis of covariance (ANCOVA) was conducted.  The independent

variable, structure, included two levels: lower amount of structure and higher amount of

structure.  The dependent variable was the PSTE and the covariate was the PSTE pretest.  A

preliminary analysis evaluating the homogeneity-of-slopes assumption indicated the relationship

between the covariate and the dependent variable did not differ significantly as a function of the

independent variable, $F(1,56) = 2.03$, $MSE = 15.95$, $\rho = .160$, partial eta squared = .035.  The

results of this test indicated the assumption of the ANCOVA had been met, thus, it was

acceptable to run the ANCOVA for this data.

Table 7 shows the ANCOVA was not significant, $F(1, 57) = 1.09$, $MSE = 16.24$, $\rho =$

.301, partial eta squared = .019.  The strength of the relationship between the independent

variable and the dependent variable was small, as assessed by the partial eta squared with

structure accounting for 2% of the variance of the dependent variable, accounting for pretest scores.  The PSTE beliefs of the two groups did not differ significantly as a result of the amount of structure present in PBL.

Table 7

*Analysis of Co-Variance for Personal Science Teaching Efficacy (PSTE) by Amount of Structure*

| Source | SS | df | MS | F | $\rho$ | $\eta^2$ |
|---|---|---|---|---|---|---|
| PSTE Pretest | 1,579.07 | 1 | 1,579.07 | 97.24 | .000 | .630 |
| Structure | 17.66 | 1 | 17.66 | 1.09 | .301 | .019 |
| Error | 925.64 | 57 | 16.24 | | | |
| Total | 166,756.00 | 60 | | | | |

**Follow-up analysis for research questions 1, 1a, and 1b.**  The ANCOVAs showed that, for this study, the amount of structure in PBL made no statistically significant difference, between groups, in science teaching efficacy belief scores.  However, follow-up paired-samples *t*-tests, shown in Table 8, comparing pretests, and posttests of all participants, both lower structure and higher structure, indicated a statistically significant increase in science teaching efficacy belief scores.

The paired-samples t-tests show that the Posttest PSTE (M = 52.27, SD = 6.95) was significantly higher than the Pretest PSTE (M = 50.93, SD = 6.74),  *t* (59) =  -2.50, $\rho$ = .015;  the Posttest STOE (M = 38.23, SD = 4.81) was significantly higher than the Pretest STOE (M = 36.5, SD = 4.48), *t* (59) = -3.16, $\rho$ = .002; and that the Posttest STEB (M = 90.50, SD = 8.24) was significantly higher than the Pretest STEB (M = 87.43, SD = 7.43), *t* (59) = -4.16, $\rho < .001$.

Table 8

*Paired-samples t-Test Comparing Pretest and Posttest Group Difference in STEBI-B scores*

|  |  | *M* | *SD* | *t*(59) | $\rho$ |
|---|---|---|---|---|---|
| PSTE |  |  |  |  |  |
|  | pretest | 50.93 | 6.74 | -2.50 | .015 |
|  | posttest | 52.27 | 6.95 |  |  |
| STOE |  |  |  |  |  |
|  | pretest | 36.50 | 4.48 | -3.16 | .002 |
|  | posttest | 38.23 | 4.81 |  |  |
| STEB |  |  |  |  |  |
|  | pretest | 87.43 | 7.43 | -4.16 | .000 |
|  | posttest | 90.50 | 8.24 |  |  |

*Note*. PSTE = Personal Science Teaching Efficacy Beliefs; STOE = Science Teaching Outcome Expectancy Beliefs; STEB = Science Teaching Efficacy Beliefs.

**Research Question 2: How did science content knowledge differ between groups as the result of quantity of structure in a problem based learning environment?**

The tutor and research fidelity personnel provided blind independent scoring on the treatment groups' poster presentation assignment at the end of the PBL lesson using the presentation rubric. As reported in the reliability section, the *ICC* was .698, which indicated a "good agreement". Raters scored 14 presentations from the 14 teams. Of the 14 teams, the lower structured group consisted of six teams and the higher structured group consisted of eight

teams.  Table 9 shows group means and standard deviations for the independent samples *t*-test of science content knowledge.

Table 9

*Descriptive Statistics of Science Content Knowledge Scores (N = 14)*

| Group | N | Mean | SD |
|---|---|---|---|
| Low Structure | 6 | 8.42 | 1.62 |
| High Structure | 8 | 11.13 | 1.71 |

Results revealed a significant difference between treatment groups on science content knowledge demonstrated.  The treatment group receiving a more structured PBL scored significantly higher in demonstrated science content knowledge.  The science content knowledge demonstrated between groups was compared using an independent samples *t*-test, as shown in Table 10.  Demonstrated science content knowledge was the test variable and amount of structure was the grouping variable.  The science content knowledge demonstrated by the group with more structure ($M = 11.13$, $SD = 1.71$) was significantly higher than the science content knowledge demonstrated by the group with less structure ($M = 8.42$, $SD = 1.62$), $t (12) = -3.00$, $\rho = .011$, $d = -1.63$.

Table 10

*Independent Samples t-Test of Science Content Knowledge (SCK) Scores*

| | *Mean difference* | *Std. Error difference* | *t* | *df* | $\rho$ | *d* |
|---|---|---|---|---|---|---|
| SCK | -2.71 | .90 | -3.00 | 12 | .011 | -1.63 |

**Summary of Results**

**Summary of research question 1, 1a, and 1b. How did science teaching efficacy beliefs (STEB), including the two subscales personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE) change as the result of quantity of structure in a problem based learning environment?**

No significant differences were found between the treatment groups as evidenced by scores obtained on the Modified STEBI-B instrument. However, further analysis with paired samples t-tests indicated that science teaching efficacy scores increased significantly for both groups ($N = 60$).

**Summary of research question 2. How did science content knowledge differ as the result of quantity of structure in a problem based learning environment?**

Significant differences were seen between groups in demonstrate science content knowledge as evidenced by the independent scoring of presentations by raters, independent samples *t*-test, and Cohen's *d* analysis. The group with the higher structured PBL experience demonstrated more science content knowledge than the group with the lower amount of structure.

This chapter described the results of the quantitative and qualitative analyses designed to address the research questions.  For research question one, no significant differences were found between low structure and high structure groups as evidenced by scores obtained on the STEBI-B.  Follow up analysis comparing both groups' STEBI-B scores increased when amount of structure was not considered.  For research question two, significant increases were seen between groups in science content knowledge as evidenced by the independent scoring by research personnel.

# CHAPTER 5

## DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

### Introduction

This chapter presents a discussion of the findings and offers conclusions and recommendations. The first section summarizes the purpose and identifies the research questions. The second section, organized according to the two research questions and their subscales, discusses the findings obtained from the analyses. The third section provides conclusions and implications for teacher educators. The last section makes recommendations for future research.

### Purpose and Research Questions

The purpose of this study was to examine the effects of differing amounts of structure within a problem based learning lesson on elementary preservice teachers' STEB and science content knowledge acquisition. The science teaching efficacy belief instrument – preservice (STEBI-B), developed by Enoch's and Riggs (1990) and modified by Bleicher (2004), was used for the study. The STEBI-B and its two subscales, science teaching outcome expectancy (STOE) and personal science teaching efficacy (PSTE) were each analyzed independently.

This study addressed two research questions, the first included two subscales.

1.  How did science teaching efficacy beliefs (STEB) of elementary preservice teachers change as the result of quantity of structure in a PBL environment?

    a.  How did science teaching outcome expectancy (STOE) of elementary preservice teachers change as the result of quantity of structure in a PBL environment?

b. How did personal science teaching efficacy (PSTE) of elementary preservice teachers change as the result of quantity of structure in a PBL environment?

2. How did science content knowledge differ between groups as a result of quantity of structure in a problem based learning environment?

## Discussion

**Discussion of Research Questions 1, 1a and 1b**

The first research question addressed the change in science teaching efficacy beliefs of elementary preservice teachers as the result of quantity of structure in a PBL environment. This question included the two subscales, which measured PSTE and STOE. Based on the results obtained; question one and its two subscales are discussed together.

The data analysis of the STEBI-B found no statistically significant difference, between treatment groups, in STEBI-B scores of elementary preservice teachers as the result of quantity of structure present in the PBL environment. The core ideas to consider and the resources provided to focus research may not have been as influential as the group dynamics of the class. It was reported by the tutor and commented on by the fidelity raters, that in both groups, participants with higher science content knowledge shared a great deal of information during the collaborative small group sharing phase, as well as, in the larger class sharing phase of the PBL lesson. These contributions could have acted as a higher structure resource throughout the lesson in the low structure group. They focused the group in content and processes necessary to solve the problem. Wijnia et al., (2011) noted that too much control over structure by either the teacher or the student stifled student motivation; however, it remains to be studied if the perception of structure and loss of control would be different if the structure was designed to optimize knowledgeable individuals in group settings.

The researcher also noted background characteristics of the research participants as possible confounding variables. This researcher noted that 30% of participants listed science as their specialty, 98% had taken three or more college science courses, 45% had one, or more degrees, with 35 % having six or more science courses and 78 % of the participants had positive science experiences. It was further noted that 68% of the participants were taking their second science methods course. The implication being that the participants were successful in their past science courses, and due to positive experiences, possessed a strong self-efficacy in their ability to teach elementary science. Any treatment would have had little added effect. Students' newly entering science education programs might have greater science teaching efficacy gains.

This researcher found that even though structure did not differentiate between groups; both groups did show increases, between pretest and posttest STEBI-B scores, in STEB, PSTE, and STOE. The problem based learning instructional model, without differing structure, may have accounted for the statistically significant increase observed in scores of both groups. These results are consistent with researchers who discovered positive effects using PBL. Watters and Ginns (2000), for example, found PBL increased STOE. Other researchers reported PBL increased problem solving abilities (Cinaglia, 2002; De Simone, 2009; Logerwell, 2009; Lou et al., 2010; Park Rogers & Abell, 2008; Pease & Kuhn, 2010; Schwartz et al., 1999).

**Discussion of Research Question 2**

The second research question addressed science content knowledge differences between groups as the result of quantity of structure in a problem based learning environment. Results obtained from the presentation rubric revealed a significant difference between treatment groups in science content knowledge demonstrated. The group receiving a more structured PBL lesson, which included core ideas to consider and resources for further research, scored significantly

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higher in science content knowledge demonstrated.  These results are especially significant since Hmelo-Silver et al., (2007) and Pease (2009) indicated that an optimal amount of structure in PBL, to increase science content knowledge, had not yet been found. Structure, as used in this study, seemed to provide guidance into areas of science content most productive and beneficial to the students' learning.  It is especially interesting that students showed significant gains in science content knowledge given that no extrinsic reward was provided.  This is in agreement with tutor and rater comments that students demonstrated interest and excitement about the problem scenario in the PBL lesson.  It is a continuing goal of educators to develop students who have an intrinsic interest in the subject and to develop students who are self-directed and excited about learning rather than memorizing for an immediate exam.

**Observations**

The researcher, tutor, and fidelity checkers made the following observations during and following the course of the study.

1.  Students who experienced the problem based learning instructional model demonstrated excitement, interest, and enthusiasm for the PBL problem.

2.  Students demonstrated intrinsic motivation to solve the PBL problem.

3.  Although structure, in the form of core ideas to consider and resources for further research, did not demonstrate significant differences in science teaching efficacy belief scores, the added structure did appear to increase breadth and depth of science content knowledge areas.

4.  Participants with higher levels of science content knowledge may have acted as higher structure, thus directing the groups toward increased science content knowledge acquisition.

5.  Students expressed interest in continuing and learning more about the PBL problem.

## Conclusions and Implications

The findings of the current study have instructional implications for teacher educators and researchers using PBL with elementary preservice teachers. Barrows (1996) asked the question, "Is problem-based learning worth the trouble?" Although structure was not found to be a significant factor in PBL as it relates to science teaching efficacy beliefs, structure did have an impact on science content knowledge acquisition. Problem based learning requires educators to invest time in preparation of meaningful and complex problems. Whether structure comes in the form of core ideas, resources for further study, or class group dynamics, PBL allows students to be active rather than passive learners and encourages group interaction.

Based on the results of the statistical analyses, the follow-up interviews, and the informal observations by the tutor and raters, this researcher determined that problem based learning, containing structure, is "worth the trouble". Structure in the form of core ideas to consider and resources for further research were shown to be significant in science content knowledge acquisition. In addition, students demonstrated interest, excitement, and intrinsic motivation.

Participants with greater amounts of scientific knowledge may have provided the structure during the PBL lesson. It is unclear what impact these participants may have had on the PBL lesson and thus science teaching efficacy beliefs and content knowledge acquisition. Participants with such science knowledge might act as an integral part of the structural component without overtly controlling student direction of learning and group dynamics. This is consistent with Hmelo-Silver (2004) who stated that collaborative problem solving groups help "to distribute the cognitive load and allow students to learn in complex domains".

**Theoretical Implications of the Study**

As discussed in chapter 1, this study used the constructivist learning theory as a framework. The constructivist learning theory asserts that learners construct their own knowledge through contemplation and connections of prior and new knowledge, personal and social experiences, and interactions with the environment. The problem based learning instructional model is founded on constructivist learning theory and was used as the independent variable in this study. The methodology of the study was designed to be consistent with the constructivist learning theory.

The constructivist learning theory predicted the favorable results obtained from the use of the problem based learning instructional model. The science teaching efficacy belief scores of all participants increased as a result of participation in the study. Additionally, student interest and desire to learn more about the subject were expressed and predicted. Finally, the treatment groups demonstrated science content knowledge during the study.

**Recommendations for Future Research**

Based on this study, the following recommendations are made.

1. Although researchers have studied structure within the PBL environment, the development of an instrument that would evaluate quantity and quality of structure is needed. This would allow statistical comparison of similar PBL environments relative to various treatments. Researchers and practitioners could use this instrument to better measure the amount of structure in PBL for future research studies or evaluation of the impact of structure in PBL.

2. A research study to examine characteristics of students who do well in PBL would be beneficial. The literature provides a great deal of evidence as to how student characteristics

brought to the classroom affect success.  With more knowledge of such characteristics, especially self-efficacy, greater numbers of successful students might be expected.

3.  A research study to examine the effectiveness of PBL that also incorporates a fieldwork component would be desirable.  Students learn in various ways, therefore, an instructional model that combines PBL with "hands-on" fieldwork might further increase science content knowledge and science teaching efficacy beliefs.

4.  A PBL lesson involving stakeholder agencies, working in teams with students, might increase students' interest and investment in the problem.  This may result in increased science content knowledge, increased science teaching efficacy beliefs, and an increased sense of investment in community.

5.  It was felt by this researcher that knowledgeable individuals were an important contribution to the PBL environment.  A study to determine the effect on structure that a knowledgeable individual within the group might have on influencing the group's science teaching efficacy beliefs and science content knowledge acquisition would benefit educators using PBL.

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**APPENDICES**

# Appendix A

**(Preservice)  STEBI-B (Enochs & Riggs, 1990, modified Bleicher, 2004)**   ID Number: _____

5 = STRONGLY AGREE   4 = AGREE   3 = UNCERTAIN   2 = DISAGREE   1 = STRONGLY DISAGREE

|     |     | SA | A | UN | D | SD |
|-----|-----|----|----|----|----|----|
| 1. | When a student does better than usual in science, it is often because the teacher exerted a little extra effort. | 5 | 4 | 3 | 2 | 1 |
| 2. | I will continually find better ways to teach science. | 5 | 4 | 3 | 2 | 1 |
| 3. | Even if I try very hard, I will not teach science as well as I will most subjects. | 5 | 4 | 3 | 2 | 1 |
| 4. | When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach. | 5 | 4 | 3 | 2 | 1 |
| 5. | I know the steps necessary to teach science concepts effectively. | 5 | 4 | 3 | 2 | 1 |
| 6. | I will not be very effective in monitoring science experiments. | 5 | 4 | 3 | 2 | 1 |
| 7. | If students are underachieving in science, it is most likely due to ineffective science teaching. | 5 | 4 | 3 | 2 | 1 |
| 8. | I will generally teach science ineffectively. | 5 | 4 | 3 | 2 | 1 |
| 9. | The inadequacy of a student's science background can be overcome by good teaching. | 5 | 4 | 3 | 2 | 1 |
| 10. | The low science achievement of students cannot generally be blamed on their teachers. | 5 | 4 | 3 | 2 | 1 |
| 11. | When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher. | 5 | 4 | 3 | 2 | 1 |
| 12. | I understand science concepts well enough to be effective in teaching elementary science. | 5 | 4 | 3 | 2 | 1 |
| 13. | Increased effort in science teaching produces little change in students' science achievement. | 5 | 4 | 3 | 2 | 1 |
| 14. | The teacher is generally responsible for the achievement of students in science. | 5 | 4 | 3 | 2 | 1 |
| 15. | Students' achievement in science is directly related to their teacher's effectiveness in science teaching. | 5 | 4 | 3 | 2 | 1 |
| 16. | If parents comment that their child is showing more interest in science, it is probably due to the child's teacher. | 5 | 4 | 3 | 2 | 1 |
| 17. | I will find it difficult to explain to students why science experiments work. | 5 | 4 | 3 | 2 | 1 |
| 18. | I will typically be able to answer students' science questions. | 5 | 4 | 3 | 2 | 1 |
| 19. | I wonder if I will have the necessary skills to teach science. | 5 | 4 | 3 | 2 | 1 |
| 20. | Given a choice, I will not invite the principal to evaluate my science teaching. | 5 | 4 | 3 | 2 | 1 |
| 21. | When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand. | 5 | 4 | 3 | 2 | 1 |
| 22. | When teaching science, I will usually welcome student questions. | 5 | 4 | 3 | 2 | 1 |
| 23. | I do not know what to do to turn students on to science. | 5 | 4 | 3 | 2 | 1 |

# Appendix B

## CORE IDEAS TO CONSIDER

1. Lake Recreation
   1.1. Boating
   1.2. Swimming
   1.3. Fishing
   1.4. Class Instruction

2. Pollutants
   2.1. Trash
   2.2. Garbage
   2.3. Sewage

3. Lake Parameters
   3.1. Area and Volume
   3.2. Shoreline Length
   3.3. Shoreline Type
   3.4. Shoreline Accessibility
       3.4.1. Beaches and Docks
       3.4.2. Boat Availability
       3.4.3. Paths

4. Watershed
   4.1. Agriculture
       4.1.1. Fertilizers
       4.1.2. Pesticides and Herbicides
   4.2. Forested Areas
   4.3. Parking Lots
   4.4. Soil Types

5. Chemistry
   5.1. Dissolved Oxygen
   5.2. Turbidity
   5.3. Temperature
   5.4. pH

6. Biotic
   6.1. Bacteria
   6.2. Plants
   6.3. Micro and Macro-Invertebrates
       6.3.1. "Good Bugs"
       6.3.2. "Bad Bugs"
   6.4. Vertebrates

7. Socio-Economics
   7.1. College Economics
       7.1.1. Course Usage
       7.1.2. Campus Appeal/Recruitment
   7.2. Community Economics

**Appendix C**

**RESOURCES FOR FURTHER RESEARCH**

| Topic | Resource | Contact Information |
|---|---|---|
| Sediment analysis | Il State geological survey | |
| | Physical Plant Department | |
| Bathymetric | Dept of civil engineering | |
| Historical data | Intramural-Recreational Sports | |
| Storm event sampling | Dept of mechanical engineering and energy processes | |
| Analysis of water samples | IL EPA | |
| Fisheries survey | | |
| Phytoplankton analysis | Western Illinois University | |
| Limnological data | Zoology department info | |
| Annual Great Cardboard Boat Regatta | Recreational Sports and Services | |
| | Center for Environmental Health and Safety | |
| Planktivore Biomanipulation | Determining The Effects Of A Planktivore Biomanipulation In Campus Lake | |
| Illinois lakes polluted with mercury | DE Archives | http://archives.dailyegyptian.com/imported-20111018203805/2004/7/27/illinois-lakes-polluted-with-mercury.html |
| | Illinois Public Interest Research Group | www.Illinoispirg.org 328 S. Jefferson St., Ste. 620 Chicago, IL 60661 \| (312) 544-4433 |
| Lake use | Locals And Students Unite | Daily Egyptian > Voices |

| | To Restore Prairie | http://www.theubpost.com/se/daily-egyptian/voices/column-locals-and-students-unite-to-restore-prarie-1.1929947 |
|---|---|---|
| Architecture | Architecture portfolio | issuu.com/troy89/docs/portfolio<br><br>http://issuu.com/troy89/docs/portfolio?mode=window&pageNumber=1<br>by troy89 |
| Sports fish consumption advisory affects area lakes | The Southern | http://thesouthern.com/news/breaking/sports-fish-consumption-advisory-affects-area-lakes/article_ae11a03e-8253-5ec3-bf64-5bdce6c1400d.html |

**PROBLEM BASED LEARNING PROBLEM**
**DEPARTMENT OF PARKS AND RECREATION**


**\*\*MEMO\*\***


Date:        Aug. 19, 2013
To:          Science Education Department
From:        Jamie Jones
Subject:     Campus Lake


The Department of Parks and Recreation and the Center for Environmental Health and Safety is committed, in part, to providing quality campus facilities that are safe and clean. Therefore, we need to develop an action plan to monitor Campus Lake to insure the health and safety of students engaged in recreational activities in and around Campus Lake. We take the health and well-being of our students and the community very seriously and feel it is prudent to have an action plan in place prior to year's end.

As experts in the field of science, your analytical and problem solving skills make you especially suited to this task. The Department of Parks and Recreation and the Center for Environmental Health and Safety desire your services to (1) Determine the proper actions to verify the current condition of Campus Lake (2) Develop an action plan for correcting and maintaining the safety of Campus Lake, and (3) Present, in the form of a poster, your action plan and all supporting documentation to your department for consideration.

The scope of your action plan should include:
- Campus Lake health and safety for recreational activities
- Campus Lake watershed and lake parameters
- Biotic and abiotic factors
- Socio-economics
- Pollutants

As you may know, we are continually preparing the lake area for our fall activities. In light of this timetable, your team will need to present its plan of action no later than the first week in Sept. 2013.

**Appendix E**

**REQUEST FOR APPROVAL TO CONDUCT RESEARCH ACTIVITIES INVOLVING**

**HUMAN SUBJECTS**

**This document was pulled for privacy reasons.**

**Appendix F**

**HUMAN SUBJECTS APPROVAL**

**This document was pulled for privacy reasons.**

## PARTICIPANT CONSENT FORM

My name is Selena Sasser and I am a graduate student at Southern Illinois University-Carbondale. I am asking you to participate in my research study investigating the effects of structure in the problem based learning instructional model on science teaching efficacy beliefs of preservice teachers.

You will participate in a problem based learning lesson, which includes solving an interesting problem, working cooperatively with your peers, developing problem solving and self-directed inquiry skills, and reflection. The lesson will take approximately three class periods and conclude in September 2013.

You will take pretests and posttests. The pretests include a survey and demographic questions and the posttests include a survey, open-ended questions, and content knowledge questions. In addition, you may be chosen for a brief interview.

Participation is voluntary. If you choose not to participate in the study, you will join the lesson but your data will be excluded from data analysis.

It is important to note that your grade will in no way be affected by your choice. In fact, your professor will not know whether you participate in the study.

Data will be kept confidential within reasonable limits. Only those directly involved with this study will have access to the data. In addition, the data will be kept in a secured location that will prevent unauthorized tampering or manipulation and will be destroyed after the study is complete.

If you have any questions about the study, please contact my advisor or me.

Selena Sasser
(618) 453-4213

Dr. Kevin Wise
(618) 453-4212

Please indicate your desire to participate in this study by signing this form. Thank you!

_____

Participant Signature and Date

This study has been reviewed and approved by the SIUC Human Subjects Committee. Questions concerning your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Sponsored Projects Administration, Woody Hall C-214, Mail Code 4709, SIUC, Carbondale, Illinois 62901-4709. You can reach the office at 618-453-4533 or siuhsc@siu.edu.

**NEUTRAL GUIDING QUESTIONS**

**Neutral guiding questions the tutor may use with both PBL groups**

"The teacher assumes the role of tutor, guide, or facilitator.  The teacher sets the climate, helps students connect to the problem, sets up a work structure, visits the problem with students, revisits the problem, facilitates the production of a product or a performance, and encourages self-evaluation"….
"Teachers using PBL face the difficult task of guiding without leading and assisting without direction. Such work involves guiding students through the process of developing possible solutions, determining what they know and what they must find out, and deciding how they could answer their own questions.  As students' research and problem solve, teachers offer suggestions when students seem stuck and propose alternatives when their research or solutions do not appear to be adequate" (Delisle, 1997, p. 16).


How would you describe the problem?
What do we know?
What do we need to learn?
And what do you think of this?
Does everyone agree with what she said?
What about those of you who don't agree?
What do you think of his explanation?
Can you add to his explanation?
What led you to that conclusion?
What do you think that means?
What led you to change your mind?
What led you to choose that resource?
Are you happy with these resources?
What other resources would be useful?
What are the main ways your choices are similar or different?
Let's brainstorm other resources.
Which problem / learning issues would you like to research?
What steps will you take?
Could you explain … further?
What do you mean when you say…?
So what you're saying is…?
Tell me more.
I see.
Go on.

## DEMOGRAPHIC QUESTIONNAIRE

ID Number_____
Please answer the following questions.
Age: _____
Gender:
- o   Male
- o   Female

Race/Ethnicity: _____

Years of College: _____
Major: _____
         Specialty Area: _____
Minor: _____
Area(s) of Certification: _____
Degrees Earned _____
Science courses taken in high school:
_____
_____
_____
_____
_____
_____

Science courses taken in college (including this one):
_____
_____
_____
_____
_____

How would you describe your prior science experiences?
- o   Positive
- o   Negative

## STRUCTURED INTERVIEW

### Opening Script

Thank you for meeting with me today. My name is Selena Sasser. The purpose of this interview is to gather more information about your Problem Based Learning experience in hopes it will shed light on the need for structure in the process. Your responses will be kept as anonymous.

Self-efficacy is defined as an individual's personal beliefs about how effectively she will teach science, and how her instruction will affect science achievement of students.

### Questions
1. Did you enjoy working in groups during the lesson? Please explain.
2. What did you do during the lessons? Did you take a leadership role in your group? Why?
3. Were you ever worried that your ideas wouldn't be accepted by the group? Do you think others felt this way?
4. Were you ever worried that you would know less content knowledge than your peers? What content knowledge did you contribute to your group? Did others contribute more or less than you?
5. Did you feel you had the resources you needed to solve the problem? Time? Information? Tutor? What other resources do you wish you had had?
6. Where do you go when you need help? Instructor? Peers? Online? How did that go?
7. This research is showing that everyone's self efficacy increased significantly. Why do you think this happened? Subject knowledge? Handouts? Tutor? Working in groups?
8. How did you personally benefit from the lesson?
9. Let's say, that you are about to teach your first science lesson to your students. How do you feel about what you are about to do? Relaxed? Frustrated?
10. What specific topics or skills trouble you regarding science? What makes them troublesome?
11. Do you think your poster is a true representation of the knowledge you gained from this lesson? Explain.
12. What do you think would have made the experience better?

### Closing Script
Is there anything else you would like to share with me?

Do you think there is anything else important I need to know?

**Appendix K**

**MODIFIED SCIENCE TEACHING EFFICACY BELIEF INSTRUMENT-PRESERVICE**
**(STEBI-B)**
**SCALE ITEM EXPLANATIONS**


Science Teaching Outcome Expectancy Scale (STOE)

1, 4, 7, 9, 10, 11, 13, 14, 15, 16    (range 10 – 50)


Personal Science Teaching Efficacy Belief Scale (PSTE)

2, 3, 5, 6, 8, 12, 17, 18, 19, 20, 21, 22, 23 (range 13 – 65)


Reversed scored items 3, 6, 8, 10, 13, 17, 19, 20, 21, 23

**Table 2**
*Factor Loadings*

| Item Number | This Study (2004) Factor 2 Loadings | This Study (2004) Factor 1 Loadings | Enochs & Riggs (1990) Factor 1 Loadings | Enochs & Riggs (1990) Factor 2 Loadings |
|---|---|---|---|---|
| *Personal Science Teaching Efficacy Belief Scale* | | | | |
| 2 | 0.27 | 0.41 | 0.47 | 0.24 |
| 3 | 0.06 | 0.62 | 0.69 | -0.06 |
| 5 | 0.06 | 0.38 | 0.51 | 0.03 |
| 6 | -0.04 | 0.61 | 0.63 | 0.02 |
| 8 | -0.01 | 0.59 | 0.74 | 0.01 |
| 12 | 0.03 | 0.62 | 0.52 | 0.10 |
| 17 | 0.03 | 0.77 | 0.81 | -0.07 |
| 18 | 0.09 | 0.77 | 0.57 | 0.03 |
| 19 | 0.13 | 0.66 | 0.73 | -0.03 |
| 20 | 0.07 | 0.72 | 0.70 | -0.10 |
| 21 | 0.04 | 0.75 | 0.62 | 0.04 |
| 22 | 0.19 | 0.49 | 0.50 | 0.05 |
| 23 | 0.11 | 0.66 | 0.72 | -0.03 |
| *Science Teaching Outcome Expectancy Scale* | | | | |
|  | Factor 1 Loadings | Factor 2 Loadings | Factor 2 Loadings | Factor 1 Loadings |
| 1 | 0.08 | 0.58 | 0.47 | 0.09 |
| 4 | 0.11 | 0.69 | 0.45 | -0.08 |
| 7 | -0.25 | 0.66 | 0.47 | 0.05 |
| 9 | 0.17 | 0.38 | 0.39 | -0.02 |
| 10 | -0.05 | 0.31 | 0.33 | 0.22 |
| 11 | -0.02 | 0.52 | 0.51 | 0.09 |
| 13 | 0.10 | 0.13 | 0.22 | 0.14 |
| 14 | 0.11 | 0.63 | 0.65 | -0.05 |
| 15 | 0.10 | 0.73 | 0.76 | -0.04 |
| 16 | 0.07 | 0.63 | 0.53 | -0.02 |

**Table 3**
*Reliability Measures: Corrected Item - Total Correlations*

| Item Number | This Study (2004) | Enochs & Riggs (1990) |
|---|---|---|
| *Personal Science Teaching Efficacy Belief Scale* | | |
| 2 | 0.35 | 0.53 |
| 3 | 0.52 | 0.61 |
| 5 | 0.33 | 0.51 |
| 6 | 0.52 | 0.60 |
| 8 | 0.48 | 0.70 |
| 12 | 0.56 | 0.55 |
| 17 | 0.69 | 0.72 |
| 18 | 0.69 | 0.56 |
| 19 | 0.58 | 0.67 |
| 20 | 0.65 | 0.61 |
| 21 | 0.66 | 0.59 |
| 22 | 0.41 | 0.49 |
| 23 | 0.58 | 0.68 |
| Reliability Coefficient | 0.87 | 0.90 |
| *Science Teaching Outcome Expectancy Scale* | | |
| 1 | 0.40 | 0.42 |
| 4 | 0.51 | 0.42 |
| 7 | 0.52 | 0.46 |
| 9 | 0.30 | 0.31 |
| 10 | 0.25 | 0.41 |
| 11 | 0.36 | 0.38 |
| 13 | 0.11 | 0.26 |
| 14 | 0.46 | 0.53 |
| 15 | 0.55 | 0.63 |
| 16 | 0.47 | 0.42 |
| Reliability Coefficient | 0.72 | 0.76 |

## REQUEST TO USE STEBI-B INSTRUMENT

From: Selena Sasser (sksasser@hotmail.com)
Sent: Mon 3/18/13 3:59 PM
To:    (bob.bleicher@csuci.edu)

Dear Dr. Bleicher,

Good afternoon,

I am a doctoral student at Southern Illinois University Carbondale and wish to use your revised STEBI-B for my dissertation, EFFECTS OF STRUCTURE IN PROBLEM-BASED LEARNING ON SCIENCE TEACHING EFFICACY BELIEFS OF ELEMENTARY PRESERVICE TEACHERS, under the direction of my dissertation committee chaired by Dr. Kevin Wise.

I would like your permission to reproduce and use your instrument along with the Reliability Measures Table 3 on page 387 of Bleicher, R. E. (2004) Revisiting the STEBI-B: Measuring Self-Efficacy in Preservice Elementary Teachers, *School Science and Mathematics*, 104(8), 383-391.

If this is agreeable to you, please email me at sksasser@hotmail.com or sksasser@siu.edu.

Sincerely,

Selena K. Sasser
Science Education

**Appendix N**

**PERMISSION TO USE STEBI-B INSTRUMENT**

From: Bleicher, Bob (Bob.Bleicher@csuci.edu)
Sent: Mon 3/18/13 4:04 PM
To: Selena Sasser (sksasser@hotmail.com)
Cc: sksasser@siu.edu (sksasser@siu.edu); Bleicher, Bob (Bob.Bleicher@csuci.edu)

3 attachments (total 112.6 KB)

Pre Bleicher 2004 modified STEBI B.doc
STEBI scale item explanation.doc
SSMA Stebi proofs Bleicher.pdf

Hello Selena,

   You are welcome to use the STEBI-B.

Revised STEBI-B attached. Along with a scoring explanation and the original article proofs.

Email me if you have any questions.

Are you attending NARST or AERA this year?

Regards,

Bob

Robert E Bleicher, Ph.D.
Professor Science Education
Liberal Studies Director
Early Assessment Program Coordinator
Principal Investigator, Promoting Educational Leadership - NASA Grant
CSU-NASA/JPL Education Collaborative Liaison

# Appendix O

## PROBLEM BASED LEARNING POSTER RUBRIC

| | Accomplished 3 | Proficient 2 | Developing 1 |
|---|---|---|---|
| **Problem** | Defines problem and identifies key issues clearly, accurately, and completely. | Defines problem and identifies some key issues clearly, accurately, and completely. | Has trouble defining problem and identifying key issues. |
| **Research** | Comprehensive analysis of appropriate, sufficient, and credible information is evident. | Some analysis of appropriate and credible information is evident. | Some appropriate information exists, but may miss or ignore relevant information. |
| **Solution** | Addresses multiple contextual factors, e.g., feasibility, constraints, and resources. Solution is sensitive to all ethical, political, cultural, and environmental dimensions. | Addresses a few contextual factors and is sensitive to one of the following: ethical, political, cultural, or environmental dimensions of the problem. | Addresses few, if any, contextual factors or dimensions. |
| **Resources** | Numerous resources are present and are relevant to the action plan. All resources cited. | Resources are limited, and only somewhat relevant to the action plan. Not all resources are cited. | Resources have no connection to action plan. Few to no resources cited. |
| **Organization** | Professional appearance. Organization and flow are intuitive to reader. | Acceptable appearance. Organization and flow mostly intuitive to reader. | Unprofessional appearance. Little organization, if any and confusing to the reader. |
| **Content Knowledge** | Addresses 7 or more content knowledge areas. Exact no._____ | Addresses 4-6 content knowledge areas. Exact no._____ | Addresses less than 3 content knowledge areas. Exact no._____ |
| **Content Knowledge Areas Addressed** | | | |

**Appendix P**

**PROBLEM BASED LEARNING (PBL) WORKSHEET**

| What do we know? | What do we need to know? | What do we need to do? |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

# Appendix Q

## PROBLEM BASED LEARNING LESSON PLAN

**Primary Subject Area**: Water Quality
**Interdisciplinary Areas Possibly Covered**:  Chemistry, Biology, Mathematics, Environmental Studies, Economics, Recreational Planning, Agriculture, and Social Sciences

**Grade Level**:  College (Elementary Preservice Teachers)

**Student's Role and Problem Situation**: Students will assume the role of scientists to assess the recreational quality of their campus lake for an upcoming event.  They will present the Department of Parks and Recreation with the status of Campus Lake, an action plan to keep the lake in good order, and an action plan in case anything unfortunate happens to the lake.

Primary Goal:  Students will increase science teaching efficacy beliefs through engagement with problem based learning experiences.

Secondary Goal:  Students will develop knowledge of the interaction of water quality and recreational planning.

**Instruction of the Lessons**:
The students will be divided into two treatment groups; both of which will experience a lesson using the problem based learning instructional method.  One group will experience a problem based learning lesson which includes more structure in the form of core ideas to focus upon and resources that may be helpful in logistically solving the problem.  The other group will experience a problem based learning lesson that does not include the added structure, therefore is lacking the core ideas and resources.  This group will have more autonomy in solving the problem.

Each group of students will be divided into small groups of 4-5 and tasked with solving the problem.  The tutor will work closely with each team to help them with the PBL process.  At the end of the lesson, each team will present their solution to the class and discuss the process they used in solving the problem.

| PBL Steps | Tutor's Role | Student's Role |
|---|---|---|
| Connecting with the problem | Reads the problem to the students. Leads discussion about the problem. Refrains from correcting misinformation | Listens to the problem. Reflects on their use of campus lake and the encounters they have had with the lake. Shares thoughts related to the problem. |
| Setting up the structure | Reminds students they will be the ones solving the problem. Introduces students to the process of using the PBL chart.<br><br>PBL Organizational Chart<br>Ideas / Facts / Learning Issues / Action Plan<br><br>Ideas-Possible solutions to the problem.<br>Facts-from the problem itself or from the discussion.<br><br>Learning Issues-Needed answers to students' questions, definitions, topics to cover, etc…<br><br>Action Plan-Where to find the answers. (books, experts, internet, etc…)<br><br>*During the highly structured lesson, the tutor distributes core ideas and possible resources. | Volunteer to be recorders. The rest of the students record the chart at their seats. Discussion is continued. Respect is given to all responses. Students contribute to filling in the chart. |
| Visiting the problem | Occasionally asks students to summarize what has been recorded. Asks students to choose the best solution to the problem. Asks students to select learning issues for further research. Asks students to share how they will research the learning issue. Tells students the amount of time they can spend on independent study. | Students reread the problem. Students generate ideas for how to solve the problem. Students continue to fill out the facts and learning issues columns. Each student selects a different learning issue they think will help them solve the question or one that interests them for further research. Tells group how they will |

|  | Tutor moves from group to group to help but never gives answers. | research the issue.<br>Begins independent study. |
| --- | --- | --- |
| Revisiting the problem | Teacher assesses student reports and resources used.<br>Asks if their research supports their original solution. | Students report on their research.<br>Recorder lists new information on the chart using a new color.<br>Students may ask new questions based on new information.<br>Additional research time may be needed.<br>Students choose a solution. |
| Producing a product | Tutor gives guidelines for the letter and poster. | Students prepare a letter to the board explaining the solutions as well as two action plans.<br>Students prepare a poster including all work for the tutor and fellow students. |
| Evaluating performance and the problem | Tutor provides forms for evaluation. | Reflect on personal and group contributions, self-efficacy, and content knowledge gained. |

Adapted from Delisle (1997), pp. 26–36.

**2012 NSTA Preservice Teacher Science Standards:**

**NSTA Standard 1: Content Knowledge**
Effective teachers of science understand and articulate the knowledge and practices of contemporary science. They interrelate and interpret important concepts, ideas, and applications in their fields of licensure. Below are the elements of the standard.

Preservice teachers will:
    1a) Understand the major concepts, principles, theories, laws, and interrelationships of their fields of licensure and supporting fields as recommended by the National Science Teachers Association.
    1b) Understand the central concepts of the supporting disciplines and the supporting role of science-specific technology.
    1c) Show an understanding of state and national curriculum standards and their impact on the content knowledge necessary for teaching P-12 students.

**NSTA Standard 2: Content Pedagogy**
Effective teachers of science understand how students learn and develop scientific knowledge. Preservice teachers use scientific inquiry to develop this knowledge for all students. Below are the elements of the standard.

Preservice teachers will:
    2a) Plan multiple lessons using a variety of inquiry approaches that demonstrate their knowledge and understanding of how all students learn science.
    2b) Include active inquiry lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, relationships, and natural patterns from empirical experiences. Applications of science-specific technology are included in the lessons when appropriate.
    2c) Design instruction and assessment strategies that confront and address naïve concepts/preconceptions.

**NSTA Standard 3: Learning Environments**
Effective teachers of science are able to plan for engaging all students in science learning by setting appropriate goals that are consistent with knowledge of how students learn science and are aligned with state and national standards. The plans reflect the nature and social context of science, inquiry, and appropriate safety considerations. Candidates design and select learning activities, instructional settings, and resources--including science-specific technology, to achieve those goals; and they plan fair and equitable assessment strategies to evaluate if the learning goals are met. Below are the elements of the standard.

Preservice teachers will:

3a) Use a variety of strategies that demonstrate the candidates' knowledge and understanding of how to select the appropriate teaching and learning activities – including laboratory or field settings and applicable instruments and/or technology- to allow access so that all students learn.  These strategies are inclusive and motivating for all students.

3b) Develop lesson plans that include active inquiry lessons where students collect and interpret data using applicable science-specific technology in order to develop concepts, understand scientific processes, relationships, and natural patterns from empirical experiences.  These plans provide for equitable achievement of science literacy for all students.

3c) Plan fair and equitable assessment strategies to analyze student learning and to evaluate if the learning goals are met.  Assessment strategies are designed to continuously evaluate preconceptions and ideas that students hold and the understandings that students have formulated.

3d) Plan a learning environment and learning experiences for all students that demonstrate chemical safety, safety procedures, and the ethical treatment of living organisms within their licensure area.

**NSTA Standard 4: Safety**
Effective teachers of science can, in a P-12 classroom setting, demonstrate and maintain chemical safety, safety procedures, and the ethical treatment of living organisms needed in the P-12 science classroom appropriate to their area of licensure.  Below are the elements of the standard.

Preservice teachers will:

4a) Design activities in a P-12 classroom that demonstrate the safe and proper techniques for the preparation, storage, dispensing, supervision, and disposal of all materials used within their subject area science instruction.

4b) Design and demonstrate activities in a P-12 classroom that demonstrate an ability to implement emergency procedures and the maintenance of safety equipment, policies and procedures that comply with established state and/or national guidelines.  Candidates ensure safe science activities appropriate for the abilities of all students.

4c) Design and demonstrate activities in a P-12 classroom that demonstrate ethical decision-making with respect to the treatment of all living organisms in and out of the classroom.  They emphasize safe, humane, and ethical treatment of animals and comply with the legal restrictions on the collection, keeping, and use of living organisms.

**NSTA Standard 5: Impact on Student Learning**
Effective teachers of science provide evidence to show that P-12 students' understanding of major science concepts, principles, theories, and laws have changed as a result of instruction by the candidate and that student knowledge is at a level of understanding beyond memorization.  Candidates provide evidence for the diversity of students they teach.  Below are the elements of the standard.

Preservice teachers will:

5a) Collect, organize, analyze, and reflect on diagnostic, formative and summative evidence of a change in mental functioning demonstrating that scientific knowledge is gained and/or corrected.

5b) Provide data to show that P-12 students are able to distinguish science from nonscience, understand the evolution and practice of science as a human endeavor, and critically analyze assertions made in the name of science.

5c) Engage students in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

**NSTA Standard 6: Professional Knowledge and Skills**

Effective teachers of science strive continuously to improve their knowledge and understanding of the ever-changing knowledge base of both content, and science pedagogy, including approaches for addressing inequities and inclusion for all students in science.  They identify with and conduct themselves as part of the science education community.  Below are the elements of the standard. Preservice teachers will:

6a) Engage in professional development opportunities in their content field such as talks, symposiums, research opportunities, or projects within their community.

6b) Engage in professional development opportunities such as conferences, research opportunities, or projects within their community.

## TUTOR PROTOCOL

### -Highly Structured-

1. Introduce problem and pass out relevant materials
2. Facilitate student learning by interacting with students to stimulate them to reflect on their knowledge without being an expert on the knowledge
3. Keep the problem challenging and obtainable
4. Monitor and stimulate group progress and interaction
5. **Anticipate content knowledge and provide core ideas needed for problem**

### -Less Structured-

1. Introduce problem and pass out relevant materials
2. Facilitate student learning by interacting with students to stimulate them to reflect on their knowledge without being an expert on the knowledge
3. Keep the problem challenging and obtainable
4. Monitor and stimulate group progress and interaction
5. **Provide little to no content knowledge and provide no core ideas needed for problem**

**Appendix S**

**FACILITATOR FIDELITY OF TREATMENT FOR PROBLEM BASED LEARNING**

| Facilitator: | Observed | Not Observed |
|---|---|---|
| Prepared and knowledgeable of subject and PBL instruction | | |
| Works to establish student ownership of problem | | |
| Establishes a supportive and constructive dialogue | | |
| Facilitates construction of students' prior knowledge | | |
| Listens actively to students' contributions and provides appropriate level of guidance and support | | |
| Stimulates students to formulate in–depth ideas | | |
| Assists students to organize knowledge into meaningful structures | | |
| Stimulates students to reflect on contributions to discussion | | |
| Does not dominate discussions | | |
| Ensures arrangements are made for working procedures, participation, and group roles | | |
| Anticipates and helps resolve problematic behavior of group members | | |
| Assists students to reflect about their knowledge | | |
| Assists students in consulting experts as learning resources | | |

Adapted from  Delisle (1997) and van Berkel, Scherpbier, Hillen, & Van der Vleuten (2010).

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