12-18-2014

Teacher Beliefs and Practices in Designing and Implementing Problem Based Learning in the Secondary Mathematics Classroom: A Case Study

Umamaheswari Subramanian

ACCEPTANCE

This dissertation, TEACHER BELIEFS AND PRACTICES IN DESIGNING AND IMPLEMENTING PROBLEM BASED LEARNING IN THE SECONDARY MATHEMATICS CLASSROOM: A CASE STUDY by UMAMAHESWARI SUBRAMANIAN was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

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ABSTRACT

TEACHER BELIEFS AND PRACTICES IN DESIGNING AND IMPLEMENTING PROBLEM BASED LEARNING IN THE SECONDARY MATHEMATICS CLASSROOM: A CASE STUDY

By

Umamaheswari Subramanian

Problem-based learning (PBL), an instructional approach anchored in the framework of the learning theory "constructivism," is a shift toward student-centered learning; students build content knowledge and problem-solving skills by solving real world problems (Hmelo-Silver, 2004; Savery, 2006; Stepien & Gallagher, 1993). Most of the existing literature on PBL comes from the higher education setting. However, researchers (Hmelo-Silver, 2004; Maxwell, Mergendoller, & Bellisimo, 2005; Ravitz, 2009; Savery, 2006; Strobel & van Barneveld, 2009) have stressed the need for more PBL research that examines its effectiveness in the K through 12 classrooms. The purpose of this dissertation study was to examine the factors affecting teachers' design and implementation of PBL in the high school mathematics classroom after a prolonged engagement in a professional learning on PBL implementation.

The research question for the study was: *After prolonged engagement in professional learning on problem-based learning (PBL), what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?* The research question was answered by examining the changes in teachers' beliefs about mathematics teaching and learning, changes in their instructional practices and by analyzing their challenges while implementing PBL in the classroom. This dissertation uses the characteristics of PBL (Savery & Duffy, 2001) as a framework, and Green's (1971) analysis of beliefs as a lens, to answer the research question.

A qualitative case study approach was selected in the current study and teacher beliefs, instructional practices were analyzed (Merriam, 1988 and Yin, 1989). Teachers from a high school located in an urban area in the southeastern region of the United States participated in a prolonged professional development on PBL for a total of 60 hours each year by being a part of the project called “Collaboration for Mathematics and Science Achievement” during 2011, and 2012. Three teachers that attended both professional development sessions were purposefully selected for this case study. I collected data through surveys, interviews, and observations and also utilized field notes and teachers’ journal entries. Results of this dissertation could be beneficial to classroom teachers and could influence curriculum writers to support classroom teachers in implementing PBL in the mathematics classroom.

The findings from this qualitative research study revealed four major themes: 1) Teacher collaboration is essential in influencing teacher beliefs in the design and implementation of PBL, 2) Pressure from the school district to increase students test scores in standardized tests prioritized learning of mathematics in the classroom, 3) Changes in terms of teaching assignment, and changes in the current curriculum discouraged teachers from embracing any innovative reform-based instructional practices like PBL in the classroom and 4) Low expectations in students’ ability and performance dissuaded teachers from implementing reform-based instructional practices like PBL in the classroom.

A major implication from the current study is that in general, teachers should hold the core belief that “All students can learn.” This statement implies that all students can learn according to the standards set forth by challenging curriculum. Mathematics teachers will have to create opportunities for students to explore inquiry-based lessons and cognitively demanding tasks such as PBL cases.

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A Dissertation

Presented in Partial Fulfillment of Requirements for the

Degree of

Doctor of Philosophy

in

Teaching and Learning

in

the Department of Middle-Secondary Education

in

the College of Education

Georgia State University

Atlanta, Georgia

2014

ACKNOWLEDGMENTS

A long list of academic professionals, family members and friends have been instrumental in me completing this dissertation. I thank all of them, though I will be able to mention only a few.

First and foremost, I thank Dr. Christine Thomas, for having taken me under her wings as an advisee even though I had not taken classes from her. I thank her for the positive attitude she had always portrayed, that was reflected in her feedback at all times. I thank Dr. Thomas for the confidence she had in me when she asked me if I could run a professional development on Problem Based Learning, thus starting my journey into my dissertation. My dissertation journey was always smooth and I enjoyed the entire process; the lengthy meetings I had with Dr. Thomas about the Teacher Quality Project, the meetings/ discussion on my dissertation chapters; I never felt frustrated in my long journey and I owe it to Dr. Thomas as my advisor.

I thank all of my committee members for having guided me in my perspectives and my defense. I thank Dr. Esposito for all the support and guidance she had given me throughout my doctoral program. I really enjoyed her qualitative courses and I thank her for inspiring me to choose a qualitative study. I thank Dr. Pier Junor Clarke for all the support and guidance she had given me throughout my doctoral program. I thank her for her time and guidance during one of the classes in helping me to write a cohesive literature review with smooth transitions. I thank Dr. Anton Puvirajah for accepting to be in my committee when I needed an additional member. I thank him for his intense and meticulous feedback that made me reflect a lot on my writing. I am thankful to my participants for sharing their PBL experiences with me.

My parents and my mother in law have been a great motivating factor in me completing my dissertation successfully. I thank them for their constant inquiry about my dissertation status from the eastern part of the world. I thank all of my friends, some of whom have helped me by reading and editing my writing. Last, but not the least, I thank my husband Venkat, daughter Poornima and my sister Rama for the support they had given me in completing my day to day chores and for taking care of me throughout my doctorate program.

Dedicated to all my students who have been a great inspiration to me at all times.

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History of Problem-Based Learning

Problem-based learning (PBL) is an instructional approach anchored in the framework of constructivism- a theory of learning. PBL has existed in medical schools for the past four decades and has entered other college-level courses as well as high school science and mathematics courses in the last decade. According to Savery (2006), in the early 1990s, medical school administrators thought that teaching subjects like anatomy and neurology in isolation and using traditional approaches, where lecturing was the only method of instruction was not effective because the knowledge base in those fields expands at a fast pace. Savery (2006) opines that the lack of effectiveness of traditional teaching methods to prepare students to diagnose clinical patients gave birth to the PBL approach and was adopted by a number of medical schools in Europe and North America.

Schmidt (1983), similar to Savery (2006), provides a similar rationale for the birth of PBL. Medical school students were often challenged to learn obsolete topics, and they faced difficulty when attempting to connect various disciplines to form a cohesive body of knowledge that could be utilized in clinical practice. When diagnosing patients, these medical school students failed half the time but had high scores on multiple-choice tests assessing the same knowledge. This inability to apply theoretical knowledge in the real world was also true of students in other disciplines. Thus, PBL was introduced as an instructional approach with a specific learning outcome of enabling students to apply their knowledge in real-world scenarios (Schmidt, 1983).

Donner and Bickley (1993) provide an overview of PBL in the medical field, identifying McMaster University in Canada as the first to offer problem-based medical curriculum to students in a nontraditional setting (in 1969) and also stating that the University of New Mexico offered PBL curriculum in 1979 alongside traditional curriculum for its medical students. Mercer University's School of Medicine was the first medical institution in the United States to offer a complete PBL curriculum from its inception in 1982. They were followed by Harvard University's School of Medicine, which initially adopted a PBL curriculum as an alternative track but later made it the standard curriculum for all medical courses despite political and financial challenges (Donner & Bickley, 1993).

As universities adopted the PBL approach, many researchers (Gijbels, Dochy, Bossche, & Segers, 2005; Ravitz, 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009) examined its effectiveness as compared to traditional curriculum. The findings from these studies were mixed: PBL is more effective if the assessment is based upon application of knowledge (Gijbels, Dochy, Bossche, & Segers, 2005); traditional learning methods (lecture method and direct instructions) were effective when the assessment types included multiple choice questions, true or false statements (Strobel & van Barneveld, 2009). Problem-based learning encourages learning specific concepts-solving problems in the same environment the problems are likely to occur in the real world. This could be a factor that led other schools to adopt the PBL approach (Savery, 2006; Schmidt, 1983). Hmelo-Silver (2004) defines self-directed learning as the ability developed by students to learn what is required to be learned in order to solve a problem after identifying what they do know and what they do not know.

Self-directed learning, once developed can be utilized for learning in new contexts. A flexible knowledge base involves the acquisition of knowledge that can be transferred to new problem situations. Self-directed learning (SDL), effective problem-solving skills and flexible knowledge base are some specified learning outcomes of PBL (Hmelo-Silver, 2004). Problem-based learning is designed to do more than simply help students retain factual information; it prepares students to apply their knowledge when solving real-world problems via self-directed learning and collaboration. According to Gijbels, Dochy, Bossche, and Segers (2005), several studies have shown PBL's effectiveness at the university level where students were tested on applying knowledge rather than recalling it.

Donner and Bickley (1993) attribute the PBL's growth in medical schools to both the exponential growth of medical knowledge and the successful implementation of PBL curriculum at Mercer University. In addition, PBL was adopted by other disciplines (e.g., engineering, economics) and various medical domains, and it spread to elementary, middle, and high schools (Bridges & Hallinger, 1997; Savery, 2006). Often, high school students and college graduates have knowledge that they are unable to apply because they are not familiar with the context of the actual problem. This inability to apply knowledge in unfamiliar contexts led to PBL being introduced at the university level in other fields, such as educational leadership and teacher education, and also at the high school level (Schimdt, 1983).

The Illinois Mathematics and Science Academy (IMSA), since 1985, has been the pioneer in providing complete PBL curricula for high school science and mathematics (Savery, 2006). A national center for PBL was initiated by the IMSA to conduct research and provide PBL training and support in Kindergarten through 16 (K-16) class settings. IMSA established a network on PBL to promote its mission of exploring PBL and mentoring educators in the use of

PBL. The PBL network was established in 1996 with the financial support of Hitachi Foundation and Harris Family Foundation. The goal of the PBL network is to help educators comprehend from the standpoint of designing, learning, coaching, and supervising. The network also encourages the use of PBL in K -16 classrooms through teaching and research (Dods, 1996). Middle school and high school students at the IMSA assume the roles of scientists, politicians, doctors, activists, artists, and historians to solve authentic real world problems. Students at the IMSA explore issues such as nuclear waste and nuclear disposal, new bacterium outbreaks and methods to control these outbreaks, and Nazi philosophies and the ways these philosophies are reflected in art and other arenas (Stepien & Gallagher, 1993). A number of teacher-training programs and undergraduate courses in various disciplines have implemented PBL curriculum; thus, PBL is now found in K through 16 classrooms across various disciplines (Savery, 2006).

Problem Statement

Problem-based learning, an instructional approach anchored in the framework of the learning theory "constructivism," is thought to improve standards, motivate bored students, and build students' critical thinking and reasoning skills (Delisle, 1997). Problem-based learning is a shift toward student-centered learning, in which students build content knowledge and problem-solving skills by solving real world problems (Hmelo-Silver, 2004; Savery, 2006; Stepien & Gallagher, 1993). The student-centered PBL instructional strategies promote creativity and help students take ownership of their learning (Delisle, 1997). Problem-based learning uses an ill-defined problem (open-ended problem that can be solved using various approaches) that could occur in the real world to recall students' existing knowledge to aid the development of new knowledge that can be applied repeatedly if required to solve the problem (Bridges & Hallinger, 1992).

Most of the existing literature on PBL comes from the higher education setting. However, researchers (Hmelo-Silver, 2004; Maxwell, Mergendoller, & Bellisimo, 2005; Ravitz, 2009; Savery, 2006; Strobel & van Barneveld, 2009) have stressed the need for PBL research that examines its effectiveness in the K through 12 classrooms. Maxwell, Mergendoller, and Bellisimo (2005) indicated that future study of the effectiveness of PBL should be focused on factors such as (a) time spent on the PBL, (b) teacher training and readiness, (c) teacher experience, (d) student types, (e) student readiness, and (f) student ability. Research at the high school level should also be focused on whether a teacher independently implements PBL in his or her classroom or if the entire school uses PBL. Little, if any, research has related the effectiveness of PBL and student learning to teachers and their beliefs and practices. This lack of teachers' perspectives necessitates an investigation of teacher-related factors that make designing and implementing PBL possible at the high school level. An in-depth understanding of teachers' beliefs on the use of PBL in the high school classroom can help curriculum designers and professional development staffs plan effectively to support teachers who utilize PBL.

Purpose

The purpose of the current study was to illuminate factors affecting teachers' design and implementation of PBL in the mathematics classroom after a prolonged engagement in professional learning academic sessions on PBL implementation. The study explored the *changes in teachers' beliefs* and the *changes in instructional practices* that resulted from designing and implementing PBL cases in the classroom. The study also examined teachers' *challenges and achievements* when attempting to use PBL. The National Council of Teachers of Mathematics (NCTM, 2009), the newly founded initiative "Common Core State Standards Initiative" (CCSSI) (2011), and researchers in mathematics education encourage a shift to student-centered instruction, emphasizing that students should be able to reason, think critically, solve problems, and make wise decisions in the real world (Ball, Ferrini-Mundy, Kilpatrick, Milgram, Schmid, & Schaar, 2005). All of the aforementioned characteristics, specifically reasoning, critical thinking, solving problems, and making decisions, are embedded in a bona fide PBL classroom (Bridges & Hallinger, 1992; Delisle, 1997; Donner & Bickley, 1993; Edens, 2000; Hmelo-Silver, 2004; Savery, 2006; Stepien & Gallagher, 1993).

Research Questions

The objective of this current study was to understand and illuminate the factors influencing teachers' beliefs in the design and implementation of PBL in mathematics classrooms. In the current study, PBL represents the instructional approach "problem-based learning," as described by Barrows (1985, 1986, 1992). Beliefs represent the personal judgments about mathematics, its learning, and teaching formulated from experiences in mathematics (Raymond, 1997) and instructional practices represent practices followed by teachers in their classrooms on a regular basis. The primary research question was, "After prolonged engagement in professional learning on problem-based learning (PBL), what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" The following sub-questions were developed to guide this inquiry:

a) How are teachers' beliefs affected through a process of designing and implementing PBL cases in the mathematics classroom?
b) How are teachers' instructional practices affected through designing and implementing PBL cases in the mathematics classroom?
c) How do teachers address challenges in implementing PBL in the mathematics classroom?

In my study, beliefs refer to beliefs pertaining to teaching and learning of mathematics acquired from experiences.

Research Design

The current study was based on professional learning involving a group of teachers from one high school and was developed to help me understand changes in mathematics teachers' beliefs and practices during the study period that involved teacher engagement with PBL. Teachers were engaged for a prolonged period of two consecutive years in professional learning focused on PBL. The professional learning consisted of 20 mathematics and science teachers (called teacher participants) from a high school located in an urban area in the southeastern region of the United States who participated in a project referred as "Project Success in Problem Based Learning" (PSPBL) during the summer of 2011. These teacher participants also participated in PSPBL II during the summer of 2012. The PSPBL project was funded by the Improving Teacher Quality state grant, which is part of a U.S. Department of Education program developed to increase students' academic achievement levels by enhancing the quality of teachers and principals in schools. Teacher quality grants are awarded for projects providing professional development for teachers in language arts, mathematics, reading, science, and social studies. The teacher quality program promotes the improvement of student learning by providing teachers with professional development that deepens their content knowledge, with the intention of improving their teaching practices.

The goals of the PSPBL project were to (1) educate practicing mathematics and science teachers on PBL pedagogy and its power to motivate students in learning the Common Core Georgia Performance Standards (CCGPS) and (2) empower practicing mathematics and science teachers in creating their own PBL cases to use in their classrooms for improving students' reasoning and critical thinking skills while simultaneously learning mathematics and science concepts. This project was developed to empower these teacher participants to create their own resources, in the form of problems, based on content-related concepts.

The PSPBL project was implemented during the summer of 2011as a weeklong academic session, and also during the follow-up sessions that occurred throughout the following academic year. During the first two days of the week long summer academic session, the focus was on implementing PBL in the classroom, and teacher participants were engaged in PBL cases that involved the use of technology (e.g., Geometers sketchpad) and hands-on scientific experiments involving ill-structured, real-world problems. During the final three days of the workshop, teacher participants created PBL cases that they could implement in their own classrooms, utilizing standards specific to their disciplines and from other disciplines when necessary. Teacher participants brainstormed about resources required to implement the PBL cases they created and also about other challenges they might face during PBL implementation in their classroom; they also assessed PBLs for validity and efficacy using a team-generated rubric. The two follow-up sessions held during the academic year were focused on the implementation of PBL in their classrooms.

As a continuation of the PSPBL project, PSPBL II was developed with a goal of empowering practicing mathematics and science teachers to enhance their PBL cases by incorporating a technology component to aid the improvement of students' reasoning and critical thinking skills. Teacher participants attended a weeklong academic session during the summer of 2012. During that week, teacher participants explored PBL cases using various methods and devices. They worked with Geometer's sketchpad, used TI-NSPIRE calculators, used Calculator-Based Laboratory (CBL) and Calculator-Based Recorder (CBR) to investigate distance velocity graphs, and conducted experiments using TI probes and vernier probes. During this same session, teacher participants also shared information about web-based resources and tools (e.g., blogs, Google documents and surveys, videos) that facilitate teaching, learning, and assessment. Teacher participants also designed PBL cases using other forms of online technology that could be implemented in their classrooms. Teacher participants attended another follow-up session in the fall of 2012, in which they shared their experiences with PBL as well as their experiences with the technology they were using in their classrooms.

Conceptual Framework

The conceptual framework of the current study served to help us understand changes in teachers' beliefs and instructional practices after a professional development and prolonged engagement in PBL. This framework is drawn from characteristics of PBL (Savery & Duffy, 1995), which is grounded in the learning theory constructivism. Changing their beliefs is essential for teachers' development; it is important to understand not only what teachers believe but also how their beliefs are structured and held (Cooney, Shealy, & Arvold, 1998). The three dimensions of belief structures (Green, 1971) also served as lens to analyze teachers' beliefs.

Problem-Based Learning and Constructivism

Advocates of PBL claim that it is a constructivist instructional model (Berkel & Schmidt, 2000; Edens, 2000; Savery & Duffy; 1995). Savery and Duffy (1995) purport that PBL is modeled after constructivism for several reasons: (a) PBL, as described by Barrows (1985, 1986, 1992), enables learners to construct their own knowledge through lively engagement in authentic tasks that are vital to the environment, and (b) Students must collaborate both creatively and critically to find solutions that every member of the group agrees with. Researchers and educators have used constructivism to understand learning for the past three decades, but there has been a lack of mathematics-specific models. Constructivism did not provide a vision for constructivist teaching and learning (Simon, 1995). According to Barrows (1985, 1986, 1992), PBL is one of the most appropriate pedagogical strategies designed after the constructivist understanding of learning (as seen in Savery & Duffy, 2001). Principles of constructivism and how PBL aligns with constructivism is discussed in this section.

Mathematics reform encourages constructivism in the classroom and in teacher training, and constructivist theory dominates learning in the mathematics classroom (Cooney, 1994; Lerman, 1989; Noddings, 1990; Pirie & Kieren, 1992). Noddings (1990) opines that despite conceptual differences, all constructivists agree on the following: (a) all knowledge is constructed, and this construction occurs when cognitive structures are activated and (b) cognitive structures are continuously changing, and it takes relevant activities to transform the cognitive structures and make them permanent. Noddings (1990) adds that mathematics constructivists believe that knowledge is constructed even when rote learning occurs and that no activity is passive, which implies that all mental activity involves some kind of construction. The constructions are strong, weak, or faulty for the same situations for different students resulting from varied pre-requisite skills and different ability levels.

As Noddings (1990) informs us, the mathematics teacher who believes that "all knowledge is constructed by students" can create an atmosphere within the classroom that promotes strong acts of constructions that result in a good understanding of mathematics. Promoting strong constructions for good understanding can be achieved if teachers maintain a highly interactive classroom through questioning, by making classroom activities relevant, meaningful, and related to students' experiences, allowing students to conjecture, hypothesize and prove and also through the use of manipulative and software programs. Teachers must have consistent practices in the mathematics classroom to create a constructivist atmosphere (Noddings, 1990). Noddings also concurs with Pirie and Kieren (1992) regarding the use of didactic lecture as a premise for constructivist learning theory. Many constructivists advocate having students in groups (communities) that are formed strategically to help students make powerful constructions through discussions taking place in the groups. Noddings (1990) cautions the requirement of the community to be a mathematical community to promote 'strong constructions'. A teacher implementing an authentic PBL classroom implements all of the above (Hmeleo-Silver, 2004; Savery and Duffy, 1995)

Cobb (1994) identifies the complementary nature of constructivist perspectives and sociocultural perspectives, stating that "Mathematical learning should be viewed as both a process of active individual construction and a process of enculturation into the mathematical practices of wider society" (p. 13). Cobb further suggests that mathematics teachers are responsible for resolving conflicts between students' personally constructed meanings of mathematics and the culturally established meaning.

Savery and Duffy (2001) used three philosophical principles to define constructivism: (1) understanding is the result of the learner's goals, actions, and interactions with the material and the situation, (2) the intellectual perplexity that arises from learning stimulates learning, and (3) knowledge is gained through mediation among collaborative groups. Cooperative learning and collaborative learning are highly encouraged even without the constructive frame of reference. Hooker, (2011) stresses the importance of having collaborative groups to improve mathematical perseverance and achievement in mathematics. Cooperative learning improves mathematical understanding, students' self-confidence and achievement (Zakaria, Solfitri, Daud, & Abidin, 2013). Cooperative learning helps in reducing mathematics anxiety and increase academic performance (Daneshamooz, & Alamolhodaei, 2012).

Savery and Duffy (2001) utilized the seven values of the constructivist framework, (1) collaboration, (2) personal autonomy, (3) generativity, (4) reflectivity, (5) active engagement, (6) personal relevance, and (7) pluralism (as proposed by Lebow, 1993), to develop eight constructivist instructional principles. Table 1 presents a comparison of constructivism's instructional principles and the characteristics of a PBL classroom as defined by Savery and Duffy (2001). In the current study, these characteristics guided the data analysis as it relates to instructional practices in the PBL classroom.

Table 1

A Comparison of Constructivist Principles and Characteristics of a PBL Classroom

Constructivist Instructional Principles	Characteristics of PBL Classroom
All learning activities should be connected to a larger real-world problem; completing an activity should have a purpose in solving a bigger problem.	In a PBL classroom, instructions starts with the presentation of a real problem that has been generated (identified) based on the standards to be mastered
Assist the learner in developing learning goals that are consistent with the instructional goals by allowing the student to take ownership of the overall problem.	Students internalize the problem and identify learning issues- standards to be learned in order to solve the problem
Provide authentic tasks that demand cognitive challenges as seen in the real world, for example, students as mathematicians trying to prove a theorem.	PBL problems are authentic problems with multiple solutions and can be tested in the real world: in problems involving public enterprises, students can compare their solutions with what is actually taking place in the enterprise
Allow students to work in complex learning environments that are similar to environments that exist in the real world.	Students design an action plan; take roles and work on different aspects of the problem in environments that are similar to environments that exist in the real world.
Provide opportunities for students to explore the problem-solving process rather than providing them with the process.	Facilitator constantly asks questions to kindle higher order thinking amongst students and refrain from giving information
Design the learning environment to support and challenge the learner's thinking.	Students are encouraged to question one another, clarify and critiques each other's solution to the problem
Encourage testing ideas against alternative views and contexts.	Self-evaluation, peer-evaluation and reflection on problem solving process are encouraged in a PBL classroom
Provide opportunities for and support reflection on both the content learned and the learning process.	PBL process culminates with a reflective summary and knowledge abstraction by the facilitator; this encompasses definitions, concepts and general principles

Characteristics of a Problem-Based Learning Classroom Environment

Problem-based learning is a student-centered instructional approach that inspires learners to examine a real-life ill-structure d problem and solve the problem by utilizing their existing knowledge and learned theory (Savery, 2006). Advocates of PBL use different characteristics to describe the learning strategy; however, all of them agree that PBL (a) is student-centered, (b) involves ill-structured problems, (c) employs teachers as facilitators, and (d) is authentic in context (Hmelo-Silver, 2004; Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009; Savery & Duffy, 2001; Strobel & van Barneveld, 2009).

Barrows (1985, 1986, and 1992) considers the following characteristics vital in an authentic PBL classroom:

- Students are accountable for their learning, they debate about what they know and what they need to know to decide what they need to learn, and their responsibility to come up with a solution and have discussions with their peers motivates them to search for relevant information and knowledge;
- Any problem used in PBL should be ill-structured because these are the only types of problems that motivate learners and represent the real world. Ill-structured problems are problems that have multiple correct solutions (Hmelo-Silver, 2004). Ill structured problems generate multiple paths to solving the problem, demands more information for better understanding of the problem and refining the paths to correct solutions as in the case of a medical diagnosis (Barrows, 1985).
- Well-structured problems do not exist in the real world
- The solution to a problem should be based upon learning emerging from a variety of disciplines, which is true in solving real-world problems
- Students should collaborate with each other and share information to develop solutions;
- Concepts that students learn independently during the PBL process should be applied to the problem and should influence the entire group during decision making
- Students should summarize the concepts learned as well as the process of solving the problem from all perspectives as a means of reflection

- Students should complete self-evaluations and peer evaluations to emphasize self-directed learning and improve their processing skills
- Problems should be authentic, real-world problems
- PBL assessments should involve the testing of both knowledge and processes, both of which are necessary to solve a problem
- Curriculum should naturally embrace PBL as pedagogy.

Three Dimensions of Beliefs' Structures

Many researchers (English, 2008; Goldin, Rösken, & Törner, 2009; Green, 1971; McLeod & McLeod, 2002; Zollman & Mason, 1992) have examined and emphasized the importance of teachers' beliefs concerning the teaching and learning of mathematics. Green (1971) opines that formation of beliefs and the changes beliefs undergo are important aspects in the teaching process. In the literature, there are various definitions of "beliefs," meaning different notions, categorizations, and functionalities; yet, most researchers attempt to arrive at a common definition, agreeing that belief is an adaptable construct (Goldin et al., 2009). Speer (2005), along with others, agree that the terms "perceptions" or "personal views" represent "belief." Törner (2002) cites a few other definitions, such as (a) "conceptions" (Thompson, 1984), (b) "philosophy" (Ernest, 1991; Lerman, 1983), (c) "concept image" (Tall & Vinner, 1981), and (d) "world view" (Schoenfeld, 1985) (p. 75). Hence, without a common definition, it is necessary to define belief using its core characteristics to avoid misconceptions (Törner, 2002). In the current study 'beliefs' represent the personal judgments about mathematics, its learning, and teaching formulated from experiences in mathematics (Raymond, 1997) and for purposes of data analysis, Green's (1971) analysis of beliefs was adopted.

Changing someone's beliefs is changing someone's belief system, as beliefs come in clusters and is strongly connected (Goldin, 2002; Green, 1971). Goldin et al. (2009) referenced Pajares (1992) to affirm that changes in someone's belief system occurs as a last resort when his or her existing belief system becomes unsatisfactory; otherwise, new beliefs will be compartmentalized and stored separately to avoid conflict. Goldin et al. also mention that beliefs associated with mathematical sense-making constitute the identity of the self and positively influence learning. Emotions, attitudes, and beliefs constitute the affective domain in relation to mathematics education; hence, research on beliefs should be considerate of the relationships between emotions, attitudes and beliefs. Beliefs that "meet emotional needs" or "defend against pain" cannot be easily abandoned for purposes of cognition. Beliefs are structured and are connected to one another in both cognitive and affective domains (Goldin et al., 2009).

Green (1971) argues that no belief can be held in isolation and that a belief always is part of a group of beliefs. Beliefs can be acquired based on logic or based on one's attitude. Green builds his analysis using a metaphor. Beliefs are always held in groups and are part of a belief system, and can be organized using three dimensions:

1. Belief systems have a quasilogical relationship between them. Some beliefs are classified as "derived beliefs," and they are based on pre-existing beliefs; other beliefs are classified as "primary beliefs" or "elementary beliefs" because they are not derived from any other beliefs. Primary beliefs to some may be derived beliefs to others, which is where the "quasi-logical structure" enters. If a person believes that some Americans emigrated from Scotland based on the fact that his/ her parents came from Scotland, the first belief is a derived belief and it is derived from the primary belief that his/her parents emigrated

from Scotland. It is also possible for primary beliefs to become derived beliefs and it is also possible for derived beliefs to become primary beliefs.

2. Belief systems have a spatial or psychological dimension. Beliefs can be classified as "psychologically strong" or "psychologically weak" based on the importance assigned to them. Psychologically strong beliefs are core beliefs espoused without questioning and can be considered to be in the center of a circle, while psychologically weak beliefs are considered peripheral to a circle. According to this metaphor, it is possible for men to believe two incompatible things at the same time like- believing that competition is the only basis for social progress and also believing that society can be improved only by cooperation. If the two beliefs are psychologically believed as core beliefs, they are never set side by side and therefore, the contradiction is not revealed. The peripheral beliefs are prone to many changes. The logical structure and spatial structure are independent of each other.
3. Belief systems are organized in clusters that are isolated from each other and have no interaction with each other. These clusters are safeguarded by a protective shield which makes possible the possession of two conflicting, logically incompatible beliefs as core beliefs by the same individual. The characteristic of belief is not dependent on the content but is dependent on the way by which the belief is held. Beliefs that are attained based on evidence or facts are classified as evidential beliefs. These beliefs are subject to change through rational thinking when the evidence or facts changes. On the other hand, beliefs that are held opposing to evidence or without any explanations are nonevidential beliefs.

The basic premise of this framework is that the characteristic of belief is prone to change. When beliefs are modified, they are modified as parts of a belief system. Teaching and learning involves acquisition of new beliefs, modification of existing beliefs; acquisition and modification of beliefs vary from one individual to the other based on the number of existing core beliefs, peripheral beliefs , the nature of those beliefs and how the transition from core to peripheral or vice versa can take place.

Significance of the Study

Problem-based learning shows a shift from teacher-centered instruction to student-centered learning, in which students build their content knowledge and problem-solving skills by solving real-world problems that may not be well defined (Savery, 2006). In PBL, a teacher or tutor provides students with resources and instructions only when necessary and challenges students by questioning their ideas (Hoffman & Ritchie, 1997; Savery, 2006). Students learn by *knowing* and *doing*, and students are given opportunities to apply newly acquired knowledge in settings that they may encounter in the real world (Bridges & Hallinger, 1992).

The current study described various factors that influence teachers to design and implement PBL in their high school classrooms, which will be significant to educators and administrators at the high school level. Classroom teachers can benefit from the study because it makes them aware of an instructional approach built upon constructivist principles, aligned with state-supported and nationally supported pedagogy, and supported by the new initiative, Common Core Georgia Performance Standards (CCGPS). The discussion of the factors influencing participating teachers to implement PBL in their classrooms and the challenges these teachers face provided in this study will help other educators plan, design, and implement PBL in their own classrooms.

This study is also significant to curriculum writers, educators at the state level, and mathematics education researchers. CCSSI requires that mathematical practice standards be connected with content standards. The first mathematical practice standard requires students to make sense of problems and persevere until these problems are solved. Curriculum writers and others involved in education should support classroom teachers by providing appropriate problems that are interesting and meaningful to students. The current study might also influence curriculum writers to include proven PBL tasks in the mathematics curriculum.

Summary

There has been a shift in mathematics teaching from a teacher-centered approach to more student-centered learning. The process standards for mathematics designed by CCSSI (2011) and NCTM (2009) require that students acquire and practice reasoning skills, problem solving skills, decision making skills in the mathematics classroom. This calls for innovative teaching strategies and instructional practices in the classroom that motivate and inspire all learners, specifically those from urban areas. Problem-based learning, grounded in constructivism, is one of such instructional practices.

Problem-based learning is popular in medical schools and several other fields, such as engineering and health sciences. The effectiveness of PBL in these fields has been previously examined, and there have been several meta-analyses on the effectiveness of PBL in the medical field and in other undergraduate programs. There is limited study of the effectiveness of PBL in high school classrooms and little to no study of the effectiveness of PBL in the mathematics classroom. In the current study, I have contributed to the literature by examining the factors influencing teachers' beliefs and instructional practices in the designing and implementation of PBL in high school mathematics classroom.

Chapter 2

Literature Review

The purpose of the current study was to understand and illuminate factors influencing teachers' beliefs in designing and implementing problem-based learning (referred to as PBL) in the mathematics classroom. The primary research question guiding the current study was, "After a prolonged engagement in a professional learning on problem-based learning, what are the factors influencing teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" This chapter is divided into three main sections: The first section reviews the literature on PBL and identifies the gap in the literature, the second section reviews the professional development literature, and the third section reviews the literature concerning teachers' beliefs and practices.

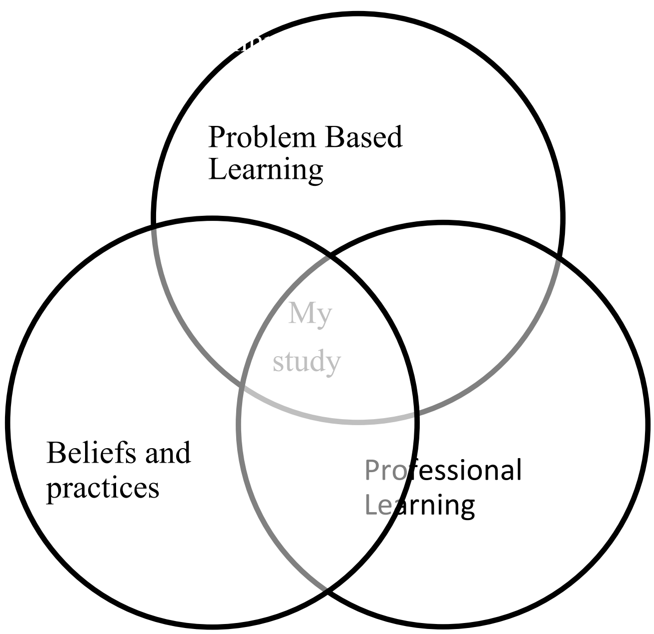

Figure 1. My Study Design

Problem-Based Learning

I begin this section by examining the current status of mathematics education in the nation and discuss research in mathematics education. Researchers, educators, and policymakers have reformed the curriculum and instructional practices in the mathematics classroom to improve education overall (Garet, Porter, Desimone, Birman, & Suk Yoon, 2001). Educational initiatives occurring earlier in the last century were indirectly targeted at student achievement through policies that were not successful; now, standards-based reform is focused on classroom instruction as means of promoting student learning (Swanson and Stevenson, 2002). The National Council of Teachers of mathematics (NCTM) published the 'Principles and Standards of School Mathematics' in 2000 emphasizing the importance of reasoning and sense making in mathematics. In 2009, NCTM published a series of books under the title 'Focus in High School Mathematics: Reasoning and Sense Making' to help teachers promote sense making in their classroom. NCTM through its publications encouraged mathematics teachers to change the role from distributor of knowledge to a facilitator role who can provide opportunities for students to conjecture, reason, argue, communicate, make sense of mathematics and explore mathematics independently and collaboratively in the classroom (NCTM, 2000, 2009).

According to the Common Core State Standards Initiative (2011), common core standards for school mathematics were created to provide American students with the skills and knowledge required to be successful not only in their careers but also in the global economy. The common core state standards for mathematics emphasize (a) mathematics-based thinking and reasoning regarding real-world issues, (b) the ability to apply mathematics knowledge to real-life situations, (c) the ability to make decisions concerning economic, social, and everyday situations and also public policy based on mathematics modeling, reasoning, and statistical analysis, and (d) the ability to strategically select the appropriate types of technology to solve mathematics problems (CCSSI, 2011). Thus, I find that reasoning, sense making, decision making, and applying mathematical knowledge to new real life situations are being emphasized in the mathematics classroom.

Apart from learning basic skills and tedious computations, students must be able to transfer their understanding, knowledge, and creativity to new situations to solve new problems. According to Pellegrino (2006), this was one of the three major critical changes developed in response to the National Center on Education and the Economy's report of the skills of the American workforce published. Thus, I find that the NCTM (the largest organization for mathematics education), the CCSSI (a newly founded initiative) encourage this shift to student-centered instruction, expecting students to be able to reason, think critically, solve problems, and make wise real-world decisions. All of these characteristics are embedded in a bona fide PBL classroom (Bridges & Hallinger, 1992; Delisle, 1997; Donner & Bickley, 1993; Edens, 2000; Hmelo-Silver, 2004; Savery, 2006; Stepien & Gallagher, 1993). The next section on characteristics of PBL describes how students learn by solving problems in a PBL classroom.

Characteristics of Problem-Based Learning

In problem-based learning, there is a shift from teacher-centered instruction to student-centered learning, in which students build content knowledge and problem-solving skills by solving real-world problems that may not be well defined (Edens, 2000; Hmelo-Silver, 2004; Savery, 2006; Stepien & Gallagher, 1993). The teacher or tutor provides students with resources and guided instructions when necessary, challenging students by questioning their ideas and thoughts (Hoffman & Ritchie, 1997; Savery, 2006). Students learn by knowing and doing, and students are given opportunities to utilize new knowledge and skills to solve problems in settings that may be encountered in the real world (Bridges & Hallinger, 1992; Savery, 2006). In PBL, there is an ill-defined problem, such as those seen in the real world, issued to students to trigger their existing knowledge to gain new knowledge that can be applied in the future (Bridges & Hallinger, 1992). Teachers lead students to be self-directed learners by modeling the behavior they want students to exhibit and activating metacognition through the use of strategic questioning (Stepien & Gallagher, 1993).

Problem-based learning has its foundation as an ill structured problem from the real world context. Hmelo-Silver (2004) defines an “ill-structured” problems as those that are open-ended (i.e., have more than one solution), require various strategies and algorithms, and require reasoning and logic. Savery (2006) emphasized the three main components of PBL as (a) ill-structured problems, (b) students being self-directed and self-regulated in their learning, and (c) teachers acting as tutors and facilitating learning by instructional scaffolding. Students do not just “cover the curriculum” in a PBL classroom, but they wrestle with ill-structured problems, struggle to understand these ever-changing, complex problems, and strive to find not the exact, but the most appropriate solution to the problem (Stepien & Gallagher, 1993).

As stated by Donner and Bickley (1993), students take an active role in the PBL classroom by asking and answering questions and taking sole responsibility of their own learning. Donner and Bickley (1993) also said that in medical education, aside from gaining complete medical knowledge, PBL curriculum demands that students apply their knowledge and that develop their outlooks, practices, and the routines to become lifelong learners. Savery (2006) insists that in a PBL setting, students should be provided opportunities to collaboratively apply the learning they have gained through independent research to solve bigger problems.

Traditional classroom experiences are not always conducive to honing students’ understanding and critical thinking skills. According to Delisle (1997), PBL is the solution to improving higher standards, motivating bored students, and building critical thinking and reasoning skills. Problem-based learning's student-centered instructional strategies promote creativity and facilitate students in gaining ownership of their learning (Delisle, 1997). In a PBL setting, students assume roles of professionals and stakeholders; taking ownership of problems as stakeholders increases the motivation needed to solve the problem (Stepien & Gallagher, 1993). In PBL problems, the use multimedia and other technology enhances students' motivation and the quality of their work (Hoffman & Ritchie, 1997).

Teachers, educators, and other leaders in education learn theory with little or no practical, real-world experience (Bridges & Hallinger, 1997; Tanner, Keedy, & Gails, 1995). Tanner et al. (1995) used an authentic PBL course to promote PBL as the most suitable approach to a principal-preparation program in which the students would face and solve real-world challenges. Bridges and Hallinger (1997) advocate the implementation of PBL courses in leadership education, claiming that complex problems situated in school environments motivate future leaders to gain new knowledge and also give them the experience of applying new knowledge in a problem-based situation to achieve results. Bridges and Hallinger (1997) also explain that PBL differs from the case method in terms of the implementation of the culminating project. Problem-based learning allows future leaders to interact in real-world situations to develop solutions to problems while the instructor guides students to a solution in the case method.

Barrows (1995) rationalizes the use of PBL as an instructional approach by referencing information processing theory, contextual learning theory, and the motivation theory. According to Barrows (1984) and Coles (1990), in information processing theory, new learning should trigger past learning, and problem situations created to imitate realistic problems facilitate the transfer of learning. According to contextual learning theory (Coles, 1990), learning makes more sense to students when the search for information is contextualized through a problem; the context of a problem necessitates the exploration and application of information. According to motivation theory (Brophy, 1991), the effort that people exert depends on the value of the rewards of the activity and the success rate of completing the activity. In a PBL scenario, a problem is both realistic and appropriate so that when students assume roles as decision makers to solve the problem, they value the solution process.

In summary, it is seen that PBL, as an instructional approach, begins with an authentic, problem that students are likely to face in the real world. It is also seen that PBL allows students to work collaboratively and gain new knowledge that can be utilized to solve problems. Problem-based learning promotes critical thinking and student inquiry and motivation. Problem-based learning is student-centered, and it empowers students to be self-directed learners.

Role of the Teacher in a Problem-Based Learning Environment

Successful implementation of PBL in the classroom depends on appropriate selection of an ill-structured problem as well as teacher facilitation provided to students through a process of questioning and scaffolding (Barrows, 1992; Hmelo-Silver, 2004; Savery, 2006). Bridges (1992) emphasizes the "tutorial process" and the role of the tutor before, during, and after a PBL session. According to Donner and Bickley (1993), the tutorial process involves small-group meetings with the instructor, during which time the instructor acts as a facilitator and ensures that the discussion is balanced and moves in the right direction. During the tutorial process, students question each other and the facilitator based on research and data that they have collected. The teacher facilitates by modeling strategies for developing higher order thinking skills and through metacognitive questioning (Hmelo-Silver, 2004).

In a PBL environment, the teacher serves as a tutor, a facilitator, and a coach that has to observe, question, challenge, motivate, and redirect students (Edens, 2000; Savery, 2006). Teachers actively participate in thinking about the problem and later act as cognitive coaches, questioning their students' thinking (Torp & Sage, 1998). During the initial stages of PBL, teachers act like students, modeling manners of collaboration, questioning, and taking ownership of a problem; as students develop self-directed learning skills, teachers assist with scaffolding and remove themselves from the problem solving process (Stepien & Gallagher, 1993).

Advantages of Problem-Based Learning Curriculum

Bridges (1992) identifies the outcomes associated with the implementation of PBL in middle school and high school classrooms as based on experiences from PBL's use in medical education environments: (1) The nature of the project in PBL allows teachers to design a focused learning environment in which students take responsibility for their own learning; (2) Students are comfortable working collaboratively and express being satisfied with learning; and (3) Students have increased levels of motivation, produce higher quality work, and are actively engaged in the PBL experience.

According to Donner and Bickley (1993), in medical field, using a variety of sources to gather information (e.g., text, monographs, periodicals) and critically evaluating sources when results seem to conflict are both advantages of using PBL; this is not found in the use of traditional curriculum. Utilizing information from critically evaluated sources helps shift students away from depending solely on lecture notes and guides them to take responsibility of their learning (Donner & Bickley, 1993; Edens, 2000). Problem-based learning pushes students to become life-long learners by encouraging self-directed learning (Hmelo-Silver, 2004).

According to Edens (2000), PBL is a constructivist instructional model that prepares students for the job market of the 21st century due to the (a) genuine context around which the PBL problem is constructed, (b) ill-structured nature of the PBL problem, and (c) open-ended nature of the possibly controversial issue, which all facilitate the attainment of problem-solving skills that are required in the job market. The most important element of PBL is that students are responsible for owning the problem as well as solving it through investigation and research.

Empirical Study of Problem-Based Learning

Various studies and meta-analyses have presented comparisons of the effectiveness of PBL curriculum and traditional curriculum. Several researchers have examined the effectiveness of PBL from an assessment perspective. Gijbels, Dochy, Bossche, and Segers (2005) performed a meta-analysis to explain the effectiveness of PBL curriculum over traditional curriculum in terms of conceptual understanding (the knowledge-concepts effect), understanding of principles and linking concepts (knowledge-principles effect), and understanding the relationship between concepts and procedures applied to solving problems (application of knowledge). The assessments were classified using a model by Sugrue (1995). Problem-based learning curriculum as defined by Barrows (1996) was compared to traditional curriculum in the meta-analysis, and the study included and assessed 40 published and unpublished studies discussed in varying terms (e.g., true/false questions, multiple-choice questions, essay questions). The different types of assessment were coded either as testing (a) knowledge-concepts effects, (b) knowledge-principles effects, or (c) the application of knowledge; one, two, or all three domains were examined. Gijbels et al.'s (2005) meta-analysis revealed that students following a PBL curriculum outperformed students following traditional curriculum in knowledge-principle effects and the application of knowledge. However, there was no significant difference between students following PBL curriculum and those following traditional curriculum in the assessment of conceptual knowledge. Solving complex problems in a realistic environment is and should be the primary aim of PBL; however, students were tested at the highest level only in 8 of the 40 studies analyzed. Gijbels et al. (2005) concluded with a caution on generalizing these findings since most of the studies analyzed were in the discipline of medicine.

Barrows (1986) created taxonomy of PBL methods, organizing the various PBL methods according to the difficulty level of the problem, the importance given to teacher-centered/student-centered learning, and the amount of information provided to students. The PBL method with more vague instructions was found to be effective, as seen in studies involving only medical students. Barrows also found that students following PBL used "backward reasoning" to solving problems. While findings (Barrows, 1986) revealed that the problem type influenced the effectiveness of the PBL method, data were insufficient to determine the particular problem type that had the most influence on learning.

Walker and Leary (2009) performed a meta-analysis of 82 studies, including 35 medicine-related studies and studies from other health-based fields that utilize PBL. Walker and Leary sought to determine the extent to which several factors influenced the outcome of PBL. These factors included discipline of study, the PBL method (as defined by Barrow, 2005), the problem type (as defined by Jonassen, 2000), level of assessment (as defined by Gijbels et al., 2005), and any combination of these factors. Walker and Leary (2009) found that students following a PBL curriculum either met or exceeded the same standards as the students learning via lecture; this was true for students from all disciplines, not only for students in the medical field.

Strobel and van Barneveld (2009) performed a meta-synthesis to analyze assumptions, definitions of learning, measurements of learning, and other results related to the effectiveness of PBL. This study included eight meta-analyses and systematic reviews comparing the effectiveness of PBL and traditional learning methods, and all of these studies, most of which were from medical education but also came from the fields of economics and computer science, included several primary studies of PBL using specified effect sizes and centered on evaluation of PBL. Strobel and van Barneveld (2009) created four final categories: (a) student and faculty satisfaction, (b) knowledge assessment, (c) performance or skill-based assessment, and (d) combined knowledge and skills assessment. In each study, PBL was favored by both students and faculty members. Assessments testing the application of knowledge and the retention of knowledge over a short time period were in favor of traditional learning approaches in some cases and in favor of PBL when tests measured free recall and anticipated free response to questions. The second type of knowledge assessment, which was focused on the long-term retention of knowledge, was in favor of PBL. The third category, performance assessment including clinical ratings and detailed essay questions, was also in favor of PBL. The last category, mixed knowledge and skill that included the assessment of medical knowledge and successful management of clinic patients, was also in favor of PBL. Strobel and van Barneveld (2009) concluded their study with a note that the discrepancy found PBL's effectiveness was due to varying definitions of "learning" and "assessment," as PBL is effective if assessment is based on long-term knowledge retention and if tested science knowledge requires detailed explanations.

Belland, Ertmer, and Simons (2006) examined the use of PBL with special needs students. The authors hypothesized that PBL is experimental, allows students to work cooperatively, and is based on real-life problem and would therefore be an excellent approach to teaching students with special needs. Belland et al. define a “special needs student” as a student with a specific cognitive or physical disability that leads them to require special education and related services. Special needs students from three different classes were assigned to determine the extent to which their home town was accessible to physically disabled citizens, and students worked for one class period per week for a semester. Belland et al. sought to (a) identify students’ perceptions regarding special needs and collaborative work while engaging in PBL, (b) discover teachers’ perceptions regarding PBL, (c) and to describe the modifications by teachers to make PBL work for students with special needs.

Data analysis (Belland et al., 2006) indicated that students and teachers saw the value of PBL. Some students valued PBL because they learned to be more patient. Other students valued PBL because it positively influenced overall motivation, granted exposure to computers and digital pictures, and improved their in grades. Teachers appreciated PBL because it allowed them to see students show compassion toward fellow classmates. Teachers also generally felt that PBL provided students with learning disabilities and those with emotional disabilities to become more mature and compassionate toward students with severe cognitive disabilities and those with multiple disorders. In addition, teachers felt that collaboration helped students improve their own social skills. Belland et al. (2006) claimed that the positive affective outcome of PBL was that instructions through PBL might be a way to improve the learning outcomes of special needs students.

Mergendoller, Maxwell, and Bellisimo (2006) compared the instructional methods in a traditional macroeconomics classroom and in a PBL-driven macroeconomics classroom. The study included 5 high school economics teachers and 346 senior students. Examining pretest and post-test scores, Mergendoller et al. (2006) found that students learned basic concepts more efficiently in the PBL setting than in a traditional setting based on pretest. There was also slight improvement in the pretest and posttest scores of students in the PBL classroom setting where students had limited verbal skills.

In summary, numerous researchers have discussed the effectiveness of PBL; however, few of these studies have been focused on students in the K through 12 classrooms setting as opposed to students at the university level (Hmelo-Silver, 2004). Public secondary education faces the challenges of funding shortages and being forced to use curriculum that is not driven by PBL; however, initiatives are emerging to circumvent these challenges and spread PBL across the K−12 curriculum (Savery, 2006). Studies of PBL have also been primarily focused on students despite a recommendation by Mergendoller et al. (2006) to include the teachers in these studies of PBL. The current study is focused on factors influencing teachers' beliefs and practices after a prolonged engagement in professional development regarding the design and implementation of PBL in the 6-12 mathematics classroom.

Professional Development

Student achievement is a direct result of effective teaching in the classroom, and effective teaching can be attained through professional development (Opfer & Pedder, 2011; Supovitz & Turner, 2000). Professional development opportunities are granted to teachers to augment their content knowledge and improve their instructional practices to keep up with the demands of student learning presented by various reforms in education (Borko, 2004). New frameworks, standards, curriculum materials, and assessments have been developed to improve mathematics education, and professional development opportunities are provided to teachers aid the improvement of their mathematical reasoning, mathematical skills, and understanding of new curriculum materials, which in turn encourages more student involvement in the learning of mathematics (Hill & Ball, 2004).

Researchers define effective professional development using varied criteria. According to Supovitz and Turner (2000), professional development in science is considered effective if most or all of the following six components are present: (1) It should help teaching through investigation, questioning, and experimentation; (2) It should be rigorous and prolonged; (3) It should relate to classroom teaching and assignments; (4) It should enhance teachers' content knowledge; (5) Teachers should relate professional development standards to student achievement; and (6) School leadership should be involved and professional development should be a part of a school's improvement plan. The U.S. Department of Education (2006) includes the above criteria in their definition of quality professional development. The U.S. Department of Education also requires that professional development include activities that promote classroom management and emphasize participation by principals, parents, and administrators as well as teachers.

Teachers play a major role in translating local, state, and national policies governing teaching strategies; teacher effectiveness is a deciding factor in the successful implementation of education reform (Garet, Porter, Desimone, Birman, & Suk Yoon, 2001). According to Garet et al. (2001), "Professional development is likely to be of higher quality if it is both sustained over time and involves a substantial number of hours" (p. 933). The Eisenhower Professional Development Program mentioned by Garet et al. was geared toward the professional development of mathematics and science teachers. Program assessment included an analysis of the relationship between three "structural features," three "core features," and teacher effectiveness in the classroom. Structural features referred to (a) type of activity, such as reform type, which includes things such as mentoring, coaching during school hours, teacher networking, study groups, and traditional workshop or conferences away from school; (b) time spent on activities and the time span of activities; and (c) the level of importance given to group participation of teachers from the same schools, subject areas, and grade levels. Core features included (a) the importance of subject focus (specifically mathematics and science) in the professional development activity; (b) the promotion of active learning by emphasizing the examination of teaching and learning through classroom activities (e.g., observation, analysis of student work); and (c) state encouragement of coherence in teachers' professional development. Teacher effectiveness was measured using changes in classroom practices, including the use of new technology and new approaches in instruction and assessment (Garet et al., 2001).

Garet et al. (2001) collected data from a national sample of 1,027 teachers who had received support from Eisenhower project funds for participating in certain types of professional development activities such as workshops, conferences, study groups, professional networks, and collaborative and peer coaching. Data included teachers' descriptions of their experiences with and changes to classroom-based instructional practices as well as descriptions of the professional development activity these teachers attended. Data were analyzed using a cause-and-effect model. Study results confirmed the effectiveness of widely accepted professional development practices, and it was found that:

1. Rigorous professional development over a longer period of time with more contact time is expected to be effective.
2. Professional development that is focused on content knowledge and active learning that provides opportunities for teachers to interact with experts and to discuss students' work

with peers, with goals aligned to reforms and standards (coherence), is more probable to produce greater outcomes in terms of knowledge and skills.

3. Coherence, in terms of connecting learning to experiences from other professional activities and professional communities, enhances change in teachers' instructional practices.
4. Group participation by teachers from the same school teaching the same subject or teaching at the same grade level plays an important role in coherence and active learning, thus indirectly impacting teacher knowledge and skills and changes in instructional practices of teachers.

Garet et al. (2001) also suggested that schools and districts focus on quality professional development for fewer teachers to produce meaningful impact on teacher learning, which directly translates into changes in instructional practice as opposed to focusing on professional development for more teachers but with no impact on learning and instructional practices.

The outcome of any student achievement-focused professional development program rests on the teachers' instructional adaptations in their classrooms (Hamilton, McCaffrey, Stecher, Klein, Robyn, & Bugliari, 2003). The National Science Foundation's (NSF) Systemic Initiatives (SI) program supported the study of the relationships between teachers' reform-based instructional practices as reported by teachers and their students' achievement, and the authors focused only on reforms introduced through this program. The primary goal of the SI program is to promote teaching practices in the classroom that would support active learning, critical thinking amongst students and increase student achievement through enriched professional development. The SI program encouraged active learning through cooperative group learning, the use of manipulative and technology, and the use of open-ended assessments. Data included students' scores on tests that were conducted by the teacher or by an administrator. Data related to the implementation of standards-based instructional practices was collected via from various surveys (Hamilton et al., 2003).

Results from Hamilton et al., (2003) indicated that higher test scores on both multiple-choice and open-ended assessments were related to frequently used reform practices; however, the correlation coefficient between test scores and reform practice was significant only at some study sites, which was true for mathematics and science. Since reform advocates inquiry and open-ended tasks, the relationship between reform practices and open-assessment scores was stronger than the relationship between reform practices and multiple-choice tests. Hamilton et al. (2003) suggest focusing on small-scale reform through instilling reform practices in teachers to identify the factors impacting student achievement.

There have been debates about teacher education and certification and student achievement. Darling-Hammond, Holtzman, Gatlin, and Heilig (2005) conducted a study of 4,408 teachers with a total combined number of 132,071 students in grades 4 and 5, finding that teachers with standard teaching certification are more successful at improving test scores than teachers with either sub-certification or no certification. Darling-Hammond et al. (2005) opine that certification basically confirms teachers' content knowledge, classroom management skills, and pedagogic skills and that teacher effectiveness improves with proper teacher training.

Focusing on specific content areas and instructional practices is an important characteristic of professional development that improves instructional practices of teachers in the classroom (Desimone, Porter, Garet, Suk Yoon, & Birman, 2002). Desimone et al. (2002) conducted a longitudinal study of 207 teachers from 30 different schools across 10 states, concluding that in addition to a focus on instructional practices and content knowledge, group participation by teachers from the same school, department or grade, coherence in terms of connecting professional development to teachers' prior knowledge and active teacher participation in learning through review of student work and other activities positively influences teachers' reform-based classroom practices.

In summary, it is obvious that professional development activities are effective in changing teachers' instructional practices if these activities are sustained, include substantial contact hours, directly relate to teachers' classroom practices, and allow teachers to interact with their peers and other experts. The professional development academic sessions examined in the current study, PSPBL I and PSPBL II, encouraged group participation by teachers from the same school. These sessions also focused on teachers' active participation in designing their own PBL cases. Each session included a total of 40 contact hours and lasted until the follow-up session at the end of the academic year. In the current study, teachers designed PBL cases that they could immediately implement in their classrooms by either working as a group or individually.

Teacher Beliefs and Practices

Moyer-Packenham, Bolyard, Kitsantas, and Oh (2008) inquired about the various instruments utilized for mathematics and science awards funded nationally. The authors found that awardees mostly assessed teachers' behaviors, practices, and beliefs as well as teachers' subject matter knowledge and pedagogical knowledge. Moyer-Packenham et al. (2008) found that surveys, questionnaires, and interviews were used to assess teachers' characteristics (e.g., behavior, beliefs, and practices) while standardized exams were used to assess teachers' knowledge in mathematics and pedagogy. The authors recognized that the characteristics assessed as "acceptable" (teachers' behaviors, beliefs, practices) play an important role in a teacher's classroom effectiveness. In addition, Watson and Geest (2005) found that principles or beliefs are more important than specific teaching methods. Teachers' beliefs about (a) mathematics and teaching and learning mathematics and (b) student competence played a major role in teachers creating a student-centered, inquiry-based (constructivist) classroom (Beswick, 2007).

The way mathematics teachers communicate mathematics to their students is influenced to a great extent by the belief structures emerging from their own learning experiences (Cooney, Shealy, & Arvold, 1998). To adapt to reform-based teaching methods, teachers must make significant changes to their belief structures through constant intervention. Hence, understanding how their belief systems are structured and held becomes an area of high importance for mathematics educators, according to Cooney et al. In addition, Cooney et al. (1998) identify context and reflection as two perspectives of understanding teachers' belief structures. The authors examined the extent to which pre-service secondary mathematics teachers develop their belief structures based on reflection and adaptability. Green's (1971) three dimensions of belief structures formed the study's theoretical framework, and purposeful selection was utilized to select study participants. Cooney et al. (1998) emphasized the importance of examining the structure of teachers' beliefs as a system and its dimensionality, which should help educators design professional development activities that inspire teachers to espouse reform (Cooney et al., 1998).

According to Middleton (1999), challenging and demanding higher order curriculum experiences structured around realistic mathematics education forces teachers to modify their existing incongruous beliefs and adapt their beliefs to create intrinsic motivation for learning mathematics. Middleton's study of two teachers participating in professional development activities that involved progressive mathematization, guided reinvention, and bridging was based on De Corte's (1995) philosophy of realistic mathematics education. Kelly's personal construct theory (1955) served as the theoretical framework. Middleton (1999) found a dramatic shift in the belief constructs of the teachers and that these teachers felt that their students started thinking at higher levels than they before and were more engaged than they were previously.

Raymond (1997) examined the relationships between beginning elementary school teachers' mathematics beliefs and teaching practices. Raymond created a model for beliefs about mathematics, identifying that a person's beliefs is shaped by his or her own classroom experiences as a students and are also highly influenced by teachers and peers. Raymond began by describing a model for beliefs and teaching practices in which the classroom is influenced by mathematics beliefs, class environment, and prior experiences and school culture. Mathematics beliefs, however, are dynamic and are influenced by changing teaching practices, prior learning experiences with mathematics, and the classroom environment. Teachers' beliefs and practices in this case study were inconsistent, as teachers had nontraditional beliefs about pedagogy but more traditional practices. Raymond found that this inconsistency stems from the fact that no significance was given to the actual belief structure—it could have existed at surface level or at a deeper level. Raymond also felt that immediate classroom situation and social norms influenced instructional practices along with beliefs.

Raymond (1997) developed a revised model of teacher beliefs and practices, in which (a) mathematics beliefs are strongly influenced by past experiences and moderately influenced by teacher education programs and teaching practices and (b) mathematics teaching practices are strongly influenced by mathematics beliefs and practices, immediate classroom situations, and social norms and slightly influenced by teacher education programs. Raymond (1997) highlighted a disturbing fact: teacher education programs have very little influence on the beliefs and practices of mathematics student teachers and should be revamped. In addition, early and continued self-examination of relationships between beliefs and practice is necessary for beginning teachers to reduce inconsistencies between beliefs and practices (Raymond, 1997).

Speer (2005) described the inconsistencies between teachers' professed and attributed beliefs, explaining that traditionally, researchers have been using common research design in which beliefs are determined using surveys, self-reports, questionnaires, interviews, and observations; practices are often collected from surveys and observations. Written or videotaped scenarios are used as prompts to generate beliefs, and stated beliefs are augmented by observations. According to Speer, these data collection methods fail to define common terminology; hence, researchers tend to give their own interpretations of beliefs and practices, resulting in inconsistencies. Kuhs and Ball (1986) (as cited in Speer, 2005) categorize beliefs about teaching and learning into (a) learner-focused, (b) content-focused, (c) content-focused with performance, and classroom-focused. When teachers describe their own beliefs, they are likely to differ from researcher inferences during observation.

According to Speer, the differences that exist between professed beliefs and attributed beliefs may be due to methodological errors or a lack of a shared understanding of descriptive terms on beliefs and practices. She further writes that Thompson (1985) found consistency between belief and practice in a teacher who viewed mathematics to be subject requiring 'mental processes' and viewed the study of mathematics as discovery and verification of ideas; this teacher encouraged students to hypothesize, guess, and discover in her class. Calderhead (1996) and Thompson (1984) coined the term 'attributed beliefs' to represent beliefs as seen in practice and in other data.

Teachers' lack of reflection and integration of beliefs with practices (Ernest, 1989) and the practical or logistical circumstances of teaching that prevent teachers from acting in accordance with their beliefs (Cooney, 2002) are two explanations given for inconsistencies in teachers' professed and attributed beliefs. However, Speer (2005) suggests faulty research design and lack of shared understanding as factors causing inconsistencies. Data on beliefs must be aligned with data on the specific practices being investigated.

Beliefs can be measured using quantitative and qualitative approaches. A quantitative approach involves the use of questionnaires recognizing the relationship between the varied structures of beliefs that can be analyzed and associated with teaching or learning practices, mathematics attitudes, and other social factors. A qualitative approach involves the analysis of data related to beliefs gathered from conversation, observations, etc.; the qualitative methodology analyses how beliefs influence problem solving, motivation, learning and teaching (Goldin et al., 2009).

In summary, many researchers have expressed the need for a holistic study of beliefs and practices that are considerate of the cognitive and affective domain and also societal aspects. The ways in which a belief system is structured plays an important role in a teacher being able to adapt to reform-based teaching methods (Cooney et al., 1998). Beliefs are responsible for individual student's learning, and problem solving and can also impact the adaptation of instructional reforms in mathematics education; belief is 'no longer a hidden variable' in mathematics research (Goldin et al., 2009).

Conclusion

The status of mathematics education as well as current trends in mathematics education research has been presented. Reform in mathematics education is shifting away from teacher-centered instruction to more robust student-centered instruction with special emphasis on students' ability to reason, think critically, solve problems, and make wise real-world decisions. The characteristics of PBL discussed in this section positions PBL as a reform-based instructional strategy. The teacher's role in the PBL classroom and PBL's advantages add merit to PBL as an instructional approach, as described in this chapter. The review of empirical studies examining the effectiveness and evaluation of PBL establishes the gap in literature that should prompt us to learn about the effectiveness and evaluation of PBL in mathematics education at the secondary level. The professional development literature frames the design of the professional development examined in the current study. The literature regarding teachers' beliefs and practices emphasizes the need for research that is focused on teachers' beliefs and practices as related to the design and implementation of problem-based learning in the 6−12 classrooms.

Chapter 3

Methodology

Problem-based learning (PBL) is an instructional approach anchored in the framework of constructivism, a theory of learning. In the current study, I have sought to identify the factors influencing teachers' beliefs and practices in the design and implementation of PBL in the mathematics classroom. The primary research question guiding the current study was, "After a prolonged engagement in a professional learning on problem-based learning, what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" The following sub questions were developed to probe the primary research question: (1) How are teachers' beliefs affected through a process of designing and implementing PBL cases in the classroom? (2) How are teachers' instructional practices affected through designing and implementing PBL cases in the classroom? and (3) How do teachers address challenges associated with implementing problem-based learning in the mathematics classroom?

This chapter is divided into six sections. In the first section, I describe the methodological orientation of the study and provide my rationale for choosing an interpretive case study. The second section describes the study design, context of the study, and study participants. The third and fourth sections are focused on data collection and analysis. Section 5 of this chapter presents a discussion of the research quality, including internal and external validity, reliability, ethics, and trustworthiness. This chapter ends with limitations to the study and a summary.

Methodological Orientation

In this section, I first discuss the rationale for choosing a qualitative study and then explain how an interpretive case study is an appropriate research design for my study. In the field of mathematics education, a range of perspectives have emerged in the literature in the past few decades, including perspectives from qualitative studies (English, 2008). As a result, there are many developments and new theories in mathematical thinking, mathematics learning, and problem solving. Knowledge played a key role in research on the teaching and learning of mathematics up until the 1970s. The advent of various theoretical frameworks led to the inclusion of metacognition, perceptions, beliefs, and problem-solving with knowledge base in the teaching and learning of mathematics (Schoenfeld, 2008). In the 1980s, research on teacher education in mathematics was focused on mathematics knowledge, stressing the importance of meaning and interpretation (Cooney, 1994). Thus, research in mathematics education has consisted of robust qualitative descriptive study along with experimental quantitative study.

Schram (2006) informs us that it is not wise to begin qualitative studies with a theory or a methodology but that a researcher must first understand that the problem and the perspective through which the problem is approached both play a role in determining the framework of a study (Schram, 2006). In the current study, I have explored the factors that influence teacher beliefs and practices in implementing PBL in the mathematics classroom. According to Lincoln and Guba (1985), research design depends on the research question being investigated. Quantitative data and methods are suitable when a research seeks to predict or prove a hypothesis; however, qualitative data can be utilized to allow us to learn about human behavior and to evaluate any discrepancies occurring from quantitative data (Guba & Lincoln, 1994). Guba and Lincoln (1994) also insist that clarity regarding the nature of the subject knowledge and how it is learned is necessary and should guide the design of the study.

Qualitative research in education can be approached in various ways and conducted in various settings. An in-depth understanding of the environment in relation to its participants is the goal of qualitative research (Merriam, 2002). In the current study, the environment was the professional learning session (academic sessions) taking place on the university campus where teachers worked collaboratively to solve PBL cases and also designed and refined PBL cases with each other's feedback. Qualitative research is not conducted to prove or disprove a hypothesis; the goal is to study human behavior using data collected from the natural environment where the action takes place (Bogdan & Biklen, 2007). Heath (1997) adds that while studying human behavior, qualitative researchers project the voice of the informants and should refrain from including their personal biases in the study. A naturalistic or qualitative study is appropriate in this case since the current study is focused on teachers' beliefs and practices (a study of human behavior) while designing and using PBL in mathematics classrooms (natural environment).

Interpretive qualitative research is aimed at identifying the experiences, interactions, and interpretations of an individual with the social world (Merriam, 2002). Interpretive research is built upon the belief that knowledge is socially constructed based on a researcher's interaction with his or her environment (Rowlings, 2005). A number of researchers agree with the definition of case study as an "exploration of a bounded system" that is focused on an incident, a setting, a situation, a subject, or a phenomenon (Merriam, 1988; Stake, 1994; Yin, 1989). A case study approach was selected in the current qualitative study not because of the focus of study, but due to the component being analyzed. Case study allows an in-depth analysis to provide a deeper understanding of a phenomenon chosen due to its distinctive, exclusive characteristics. The case study method is common in education research and is often used to aid the understanding of a unique phenomenon (Merriam, 1988, 2002). I have examined the design and implementation of PBL and explored this by analyzing changes in individual teachers' beliefs and practices.

Merriam (1988) identifies four factors to help researchers decide if case study is appropriate:

1. The first factor is the nature of the research questions. Merriam (1988) and Yin (1984) state that "how" and "why" questions are best suited for case study research. The sub questions guiding the current inquiry fit this description.
2. The second factor is the amount of control. A case study design is associated with a low level of control. The teacher participants freely designed their PBL cases and chose the times of implementation. The teacher participants had the freedom to design PBL on any topic that was aligned to standards in the curriculum and also had the freedom to implement the same at the appropriate time according to their pacing of the curriculum.
3. The third factor is the desired end product. Case study requires that the end products are either rich, intensive descriptions or interpretations of a contemporary phenomenon. In the current study, I have examined the changes regarding the beliefs and practices among a specific group of mathematics teachers' that participated in professional learning academic sessions on PBL over a 2-year span. No widely used theory is available regarding teacher's beliefs and practices related to PBL in the mathematics classroom. I have not proved or disproved a hypothesis' or explained causal effects of a particular behavior. My end product was simply an interpretation of my observations and interactions with teachers and their experiences, which is aligned with the end product of case study.
4. The last factor to be considered is whether or not the system being investigated is bounded. I have identified changes in teachers' beliefs in teaching and learning of mathematics and practices that happened in the mathematics classroom (context) during

the time of professional learning in the PSPBL (time). Hence, the current study is bounded by time and by context. My data analysis is made up of three separate units of analysis on the three case study participants chosen.

Merriam (2002) classifies case study design as descriptive, interpretive, and evaluative. Interpretive case studies use thick description and inductive analyses to hypothesize and build theory to describe the phenomenon being studied. In the current study, I have explored a bounded system in search of answers to a focused question in efforts to conceptualize and produce in-depth descriptions of understanding these beliefs and practices. The purpose of this study was best met using an interpretive case study design, as described by Merriam (1988).

Development of the Study Design

During the 2010−2011 academic year, I participated in the Problems and Research to Integrate Science and Mathematics (PRISM) fellowship that allowed me to participate in a 2-week PBL workshop that was organized by a respected University in a city located in the southeastern United States. During these two weeks, I was exposed to PBL in mathematics and science classrooms. My first activity required us—the teachers (PRISM participants) to listen to a conversation. We, the PRISM participants brainstormed to discover the hidden problem in the conversation, worked on action plans, worked independently on different aspects of the problem, and found possible solutions by brainstorming, once again, and analyzing information collected by various researchers. During this process, all group members solved the problem, developed an overview of the problem and solution, and became experts in particular areas of the problem that we were responsible for.

This experience with PBL was an amazing one when considering the fact that this method could possibly push students to think beyond the content and process standards expected in the classroom. We, the PRISM participants saw examples of various PBL s related to issues such as water pollution, Ferris wheels, and landfills in action, and spent time designing PBL to use in our classrooms. In addition to creating PBL cases, we field-tested and got feedback and constructive comments from fellow PRISM participants. Creating “the hook” to the problem and attempting to make it interesting enough to grasp students’ attention was both exciting and challenging. While the science teachers were able to easily transform newspaper articles into PBL cases, it was not as easy for mathematics teachers to create PBL cases. I spent quite a bit of the summer writing PBL cases for my classroom and implemented them in my classroom during the 2010−2011 academic year.

At this juncture, I had nearly completed my doctoral coursework and was preparing to begin my research. Up until that time, I was planning to study student perceptions of Geometer’s Sketchpad, but after attending the PBL workshop, I wanted to learn more about it and asked to change my dissertation topic. I was fascinated with designing and implementing PBL and was thrilled to see students so deeply engaged in problem solving. I started to advocate PBL when talking to colleagues and wondered why the strategy was not utilized widely despite being introduced in high school classrooms over a decade ago. My doctoral program advisor then encouraged me to conduct a PBL professional development session for teachers, but I did not know how to do this. After a few days, I was allowed to serve as a graduate research assistant to assist with writing a teacher quality grant to conduct a professional development session on the use of PBL in mathematics and science. The professional development session was slated for the summer of 2011.

The U.S. Department of Education embraces the improvement of teacher quality by providing funds for projects that offer professional development to teachers in language arts, mathematics, reading, science, and social studies. The teacher quality program seeks to improve student learning by developing teachers' content knowledge and instructional strategies. My advisor, the director of this proposed professional development project, applied for this grant and listed me as a resource person. The grant was approved in November 2010, and the professional development, entitled "Project Success in Problem Based Learning" (PSPBL), was for the mathematics and science teachers. The face-to-face meeting sessions for PSPBL are called PSPBL academic sessions. Since this was my first experience facilitating a professional development session for teachers, I meticulously planned. The positive feedback from teachers and the need for teachers to learn about the use of technology in the classroom encouraged my advisor to apply for a related grant for the next year. This grant was also approved and led to the second phase of the project, PSPBL II.

Context of the Study

During the summer of 2011, a group of 20 mathematics and science teachers from an urban high school located in the southeastern region of United States participated in the PSPBL professional development academic sessions. The high school has approximately 1,310 students, and during the 2011−2012 academic term, 96% of the student population was African American, 2% was Hispanic, and 79% of the students were eligible for free or reduced-price lunch. The ages of the teacher participants ranged from 25 to 60 years. Teacher participants had degrees that varied from a Bachelor's degree in science/mathematics to a doctorate in mathematics and mathematics education.

The PSPBL academic sessions were held on a University campus, and I facilitated this session along with another science teacher who had experience with PBL. During the PSPBL I project, teacher participants were (1) instructed on PBL pedagogy and its power to motivate students in the classroom; (2) provided the opportunity to design PBL cases that could be utilized to improve reasoning and critical thinking in their classrooms; and (3) required to implement PBL cases in their classroom. Participants spent the first two days of the academic session watching PBL in action and collaboratively solving PBL cases. They spent the next three days creating PBLs. Participants chose various Common Core Georgia Performance Standards (CCGPS) for mathematics and science to implement in their classrooms and incorporated standards from other disciplines to design PBLs as needed. Follow-up sessions consisted of meetings with the teachers as a professional learning community to reinforce a sense of community among mathematics and science teachers. Teachers evaluated each other's PBL implementation, and they also critiqued students' work and gave them feedback.

The focus of PSPBL II was the infusion of technology in PBL in mathematics and science, and I facilitated this workshop as well. Twenty-nine mathematics and science teachers from different schools in the same southeastern city convened at the University in the summer of 2012. They actively used various technologies as a natural progression of using of PBL in their classrooms. These technologies included Vernier probes, TI-Inspire calculators, Calculator-Based Laboratories and Calculator-Based Rangers, Geometer's Sketchpad, and the Internet. Teachers developed PBL cases for their students to teach the mandatory core competencies. During this academic session, teachers designed PBL cases and special emphasis was placed on incorporating technology into these PBL cases.

A total of 12 mathematics teachers participated in PSPBL I academic sessions. At this time, all of the mathematics teachers were involved as a group in designing and learning about PBL. However, at the start of the academic year, several of these teachers went to other schools or school systems. Four teacher participants strongly espoused PBL and implemented PBL in their classrooms; one of these teachers retired at the end of that year. The three mathematics teachers who participated in both PSPBL I and PSPBL II naturally became participants for the multiple-case study. When conducting a qualitative study, the focus of the research moves from the general to a specific situation. The qualitative researcher should understand meaning only through his or her participants, and hence must select participants who will yield the most knowledge and understanding (Merriam, 2002). Merriam also suggests that a qualitative researcher begins with the criteria to be used for participant selection. I selected teachers who participated in PSPBL I and PSPBL II and who also had designed PBL during PSPBLI and implemented the same in their mathematics classrooms. These three mathematics teachers, who worked at the same high school, fitted the criteria for the current study.

Researcher's Role

Interpretive case study uses thick description and inductive analysis to hypothesize and build theory describing the phenomenon studied (Merriam, 2002). I explored a bounded system (the PBL classroom) and answered a focused question to conceptualize and produce in-depth descriptions for the purpose of illuminating and understanding teachers' beliefs and practices. During PSPBL I, I was a resource person facilitating a PBL classroom introducing PBL to teachers. Teachers, in groups of four, acted as learners by participating in the PBL case and also being excited to solve the problem posed to them. I was also serving as a researcher by making observations and writing field notes. As a teacher that has used PBL in my classroom, I had seen students work on PBL cases collaboratively to arrive at a solution. While recording field notes, I was careful not to let my personal perceptions or biases influence my observations.

The Institutional Review Board (IRB) approved the study of the PSPBL projects. As a researcher, when I visited classrooms for observations, I was respectful, open, and nonjudgmental. I was also meticulous with my observations and notes. I did not allow my role as a PBL facilitator influence me during observations and during interviews. When conducting participant interviews, I met teachers at convenient locations and times and adhered to ethical standards. I have fully protected the identities of study participants by using pseudonyms, and I have employed member checking prior to data analysis.

Data Collection

Data collection for case study includes but is not limited to documentation, archival records, interviews, direct observations, participation-observation, and direct artifacts (Yin, 2009). The richly descriptive nature of qualitative study arises from the description of the data collected in the form of field notes, interviews and other documents. Using multiple data sources (e.g., interviews, observations, and documents) is the strength of case study (Merriam, 1988, 2002). Siber (1982) (as cited in Merriam, 1988) lists four ways that quantitative surveys can strengthen qualitative data, and according to Siber, a quantitative survey cautions the researcher not to assume that all data fits an emerging theory and it can help with verification and clear misinterpretations of field observations. Data collection in the current study included field notes from observations, interviews, PBL artifacts, and surveys.

During the PSPBL I project, participant teachers completed journal entries on various topics related to the design and implementation of PBL as well as their beliefs about PBL. I recorded field notes during observations on PBL related activities occurring throughout the day during the professional development academic sessions. Teachers also completed surveys both before and after the project inquiring about their beliefs and practices related to teaching and learning of mathematics using PBL. A detailed description of survey development is provided after this section on data collection. There were two follow-up sessions for the PSPBL I academic session, one in the fall 2011 and another in the spring of 2012. Participants shared their experiences with PBL during the follow-up sessions. I took field notes during both the follow-up sessions. I also took field notes during classroom observation while PBL was being implemented in one of the classrooms.

The study was focused on determining the factors that influence teachers' beliefs about designing and implementing PBL in the mathematics classroom. During the week of the PSPBL I project, teacher participants wrote daily journal entries sharing their initial thoughts about PBL, their readiness to implement it in their classrooms, the support they needed to implement PBL, their fears in implementing PBL, ways to design PBL to increase their students' reasoning abilities, and ways to convince and motivate students using PBL. The archived journal entries, field notes from observations, and surveys related to mathematics teaching and learning conducted both before and after the workshop was my first sources of data.

The second level of data included field notes from classroom observations on the first day of the implementation of a PBL unit. During classroom observation, I, as the researcher, recorded teacher instructions, students' responses to the teacher, students' group interactions, and any nonverbal cues occurring in the room. Teacher participants shared their experiences with implementing PBL with the rest of the mathematics faculty during mathematics planning time. As a researcher, I recorded field notes during these meetings as part of data collection.

Beginning data analysis after collecting the first set of data allows a researcher to redirect further data collection and ensure that data are yielding the information they need to answer the research questions (Merriam, 2002). The next set of data was collected from individual interviews of the three teacher participants. Interview questions were prepared based on journal entries and field notes to allow me to learn more about teachers' beliefs and instructional practices that were not revealed earlier. The interviews took place during the summer of 2012 after the PSPBL II academic sessions. Also serving as data were teachers' lesson plans for the PBL unit, the selected PBL task, and students' end products along with their assessment of the unit.

Survey Instrument Development

The survey instrument developed for the current study is modeled after the Standards Beliefs Instrument (SBI) created by Zollman and Mason (1992). The National Council of Teachers of Mathematics (NCTM) (1989) initiated reform in mathematics education to improve mathematics education across the nation. The NCTM developed 54 standards and emphasized "conceptual understanding, mathematical reasoning and problem solving," focusing on content and process. These standards (NCTM, 1989) also dictated roles for teachers and students, demanding that students actively participate in their learning and that teachers serve as facilitators of the learning experience. Zollman and Mason (1992) developed the SBI to assess the beliefs of teachers about NCTM standards. A "belief" is defined as "a judgment of the credibility of a conceptualization' (p. 359). The SBI included 16 statements about the standards, 8 with positive valence (i.e., agreed with these standards) and 8 with negative valence (i.e., opposed NCTM standards).

The survey created for this study included a total of 25 statements that were divided into three broad categories: (a) problem solving, (b) students and PBL, and (3) designing problems for PBL. Responses follow a 5-point Likert-type scale, with 1 representing "strongly agree," 2 representing "agree," 3 representing "neutral," 4 representing "disagree," and 5 representing "strongly disagree." From the 25 statements, I constructed 9 belief statements related to problem solving. Some of these statements are constructivist principles supported by PBL and also emphasized by NCTM standards. I constructed 10 statements related to students and PBL using

Barrow's (1985, 1986, 1992) characteristics of PBL along with the suggested advantages of using PBL. The last 6 statements were related to the design PBL that is appropriate for the class and related to mathematics standards.

This instrument was sent to an external evaluator for the PSPBL project and according to the feedback I received, all 25 statements were randomly arranged in no specific order. Content validity was ensured as I included all statements on PBL as they related to the research questions. Instrument bias was removed as I gave approximately 50% of the statements a positive valence. The survey was field tested among a group of 10 teachers before it was administered to the participants of the PSPBL academic session.

Data Analysis

All qualitative researchers agree that data analysis should almost begin with data collection while conducting a qualitative study (Merriam, 1998; Schram, 2006; Yin, 1989). The initial analysis helps with purposive sampling and also influences future data collection; however, an in-depth inductive analysis begins with the end of data collection (Merriam, 1988). Bogdan and Biklen (2007) define data analysis as:

> ...the process of systematically searching and arranging the interview transcripts, field notes, and other materials that you accumulate to increase your own understanding of them and to enable you to come up with findings. Data interpretation refers to developing ideas about your findings and relating them to the literature and to broader concerns and concepts. Analysis involves working with data, organizing them, breaking them into manageable units, synthesizing them, searching for patterns. Interpretation involves explaining and framing your ideas in relation to theory, other scholarship, and action, as well as showing why your findings are important, and making them understandable. (p. 159)

Although data collection and analysis are ongoing in case study research, Merriam (1988) warns researchers to end data collection and commence with intensive analysis by studying the situation's practicality. Merriam (1988) agrees with Lincoln and Guba (1985), who listed several guidelines to end data collection: exhaustion of sources, saturation of categories, emergence of regularities, and overextension.

I began my data analysis by creating a "case record" (Patton, 1980), which is an organized record of all data obtained from journal entries, field notes, interviews, and surveys arranged by topics and in a ready-to-use format after data has been edited and redundant information has been removed, as suggested by Merriam (1988). I incorporated a more intensive analysis by reading all of the data several times, taking notes, writing memos, and having a "virtual conversation" with the data. At that point, I searched for patterns and regularities that eventually became broad categories for coding. I initially started with the broad categories 'teacher practice, teacher belief, student behavior, and challenges'. I then read the data from the case record and coded data under the broad categories that were identified. A second more advanced and intensive analysis helped me streamline conceptual categories based on concepts related to the research questions. Some categories were based on concepts that include beliefs about mathematics, the teaching and learning of mathematics, PBL, instructional practices, etc. Conceptual categories were not explicitly visible to me as a reader; these only interpreted the meaning of the data collected. Creating conceptual categories was an intuitive process that was guided by research questions, the researcher's knowledge, and the data collected from the study participants (Merriam, 1988).

The third level of intensive analysis was creating a theory based on inferences from the second level of coding as related to the research questions (Merriam, 1988). Bogdan and Biklen (2007) encourage researchers to speculate ideas while analyzing data and to write about new ideas; they also emphasize that researchers should keep track of comments and memos while forming new ideas. Green's analysis of beliefs (1971) and Savery's (2006) characteristics of PBL have guided the completion of data analysis after coding was finished, results were interpreted, and theory was forming.

Research Quality

The value of qualitative research can be measured using concepts of validity, reliability, and trustworthiness in terms of ethical conduct (Merriam, 2002). Internal validity in any research refers to the closeness of the data and analysis to reality; however, in qualitative studies, reality refers to a researcher's understanding of participants' experiences and interpretations of the phenomenon being examined. Merriam (2002) lists triangulation, member-checking, peer review, reflexivity, and engagement in data collection until data saturation occurs as ways to ensure internal validity in qualitative research.

Triangulation is the process of gathering information from at least three data sources to ensure accuracy of the data collected (Bogdan & Biklen, 2007). In the current study, triangulation was achieved through the use of multiple data sources from the different participants, and multiple process data collection methods (e.g., observation, interview, survey). In the current study, data were collected from various sources and perspectives. Participants have confirmed the text from their transcribed interviews and the field notes, and I have discussed the discrepancies between what was said and what was observed, which is considered member checking. According to Schram (2006), validity or credibility refers to the focus of the research questions and measures how well the data and data analysis processes provide answers to the research questions. A researcher's presence and positive influence while the study takes place is one way of ensuring credibility in research (Schram, 2006). I have ensured credibility by being present, taking meticulous field notes during each observation (in addition to triangulation), and have performed member checks.

During the intensive data analysis process, I have followed guidelines by Bogdan and Biklen (2007) regarding memo writing and note taking, and I have used them to reflect on my ideas. I have collected data from the summer of 2011 up until fall of 2012. Thus, internal validity is addressed as I adhere to four of five suggestions by Merriam (2002).

Reliability in qualitative research can be interpreted as dependability or consistency in terms of the result agreeing with the data collected (Lincoln & Guba, 1985). The results of the current study may not be generalizable, as seen in any other qualitative study. The theory generated during or after data analysis is specific to that specific research situation at that time. Real-life situations cannot be duplicated in the same way and hence may not be generalizable. Dependability or consistency demands that results obtained from the data are convincing and make sense to other researchers. To be consistent, I have reminded myself my role as the researcher and the ways my subjectivity might influence results. I have kept a research journal, taken notes, explained how codes were created, reflected, asked questions, and written memos informing me to analyze data using theory without employing any personal bias. Ttriangulation, peer examination, and investigator's position along with audit trial have ensured relaibility in qualitative studies (Merriam, 2002, p. 27). The journal I have kept has served as the audit trial and has ensured reliability when used along with the three strategies mentioned above.

In qualitative research, external validity is satisfied by providing rich, thick description to help readers decide if results can be transferred to their situations depending on the closeness of their situation to that of the research problem (Merriam, 2002). I have ensured external validity by including detailed descriptions.

Ethics

A qualitative study is considered trustworthy only if conducted ethically; trustworthiness depends on internal and external validity and reliability. Validity and reliability depend on the researcher's ethical conduct, and a researcher must be prepared to resolve any ethical dilemmas that arise by making assumptions prior to conducting a study (Merriam, 2002). Bogdan and Biklen (2007) suggest a few strategies to overcome ethical dilemmas in qualitative research in education: (1) Avoid research sites where you hold an administrative or supervisory role over study participants. (2) Do not choose participants who are not comfortable sharing information with you. (3) When conducting observations or interviews choose a time and place that is convenient for study participants. (4) Preserve participants' anonymity in both oral and written communications. (5) Respect study participants and respect your contract with them. (6) Have the courage to report your findings as they are. These things were prioritized in the current study.

As a qualitative researcher, I was privileged to have a lot of personal information about study participants and have faced ethical dilemmas. I understood my responsibility as a researcher to protect informants from harm. All study data from the PSPBL I and PSPBL II academic sessions were approved by IRB and are archived. The purpose of the study, data collection methods, and time commitment, along with artifacts required from participants, have all been explained to participants, and participants had given informed consent and had the right to withdraw from the study at any time. Participants were not placed at any more risk than what they would have faced in their everyday lives. In addition, I acknowledged potential bias that might have occurred during data analysis and monitored this closely as suggested by Merriam (2002).

Study Limitations

As in any research, there are limitations to the current study. This study was qualitative in nature and was a case study involving three teacher participants. Yet, study results cannot be generalized for all high school mathematics teachers, which is one limitation of the study. Another limitation is that teachers have shared their experiences based on the implementation of only one or two PBL cases in their classroom. Implementation of more PBL cases by teachers in their classrooms would have yielded different information.

Summary

The current study was an interpretive case study. Using purposive sampling from a group of mathematics and science teachers attending two lengthy professional development sessions during the 2011−2012 and 2012−2013 academic years, referred to as PSPBL I and PSPBL II, on the design and implementation of PBL, three mathematics teachers were selected as study participants. Data collection included field notes from observations, and journal entries occurring during these academic sessions, pre- and post-surveys, interviews, classroom observation, and teachers' lesson plans. Green's (1971) analysis of beliefs and characteristics of PBL (Savery, 2006) guided the data analysis. Using triangulation, member-checking, and audit trails internal validity, external validity, reliability, and trustworthiness were adhered to in the study.

Chapter 4

Results

In the current study, I investigated changes in teachers' beliefs and instructional practices resulting from prolonged engagement in professional learning in problem-based learning (PBL). This investigation was designed to aid an understanding of the factors influencing teachers' beliefs in designing and implementing PBL in the mathematics classroom. To describe the changes in teachers' beliefs and practices, I developed the following primary research questions and sub questions. The primary research question was, "After prolonged engagement in professional learning on problem-based learning (PBL), what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" The sub questions are:

- How are teachers' beliefs affected through a process of designing and implementing PBL cases in the mathematics classroom?
- How are teachers' instructional practices affected through designing and implementing PBL cases in the mathematics classroom?
- How do teachers address challenges in implementing PBL in the mathematics classroom?

This chapter opens with a discussion on the study's context, provides details on the process of calculating survey scores, and introduces the three study participants. Participants richly described their students' behaviors and attitudes during PBL implementation. The within- and cross-case analysis utilized in the current study is replicated for each of the following categories related to participants': (a) beliefs related to mathematics teaching and learning, (b) beliefs related to student characteristics in PBL learning environments, (c) challenges related to designing and implementing PBL, and (d) students' attitudes and behaviors in the PBL environment.

Context of the Study

Three teachers participated in the current study: two African American females (referred to by the pseudonyms Jessica and Mary) and one African American male (referred to by the pseudonym George). These pseudonyms were used to protect the identities of the study-participants. The three study-participants were employed at the same public school, referred to throughout the study as Hopewell High School (HHS) (also a pseudonym). Hopewell High School is located in an urban area in the southeastern region of the United States. During my first visit to HHS, I noticed the condition of the building: an old one-story building on a large plot of land (approximately 70 acres). The faculty parking lot was on the left side of the building, and a parking lot for parents and visitors was behind the building. The faculty lot appeared to be much smaller than the parent/visitor lot. A huge reception area was at the building's entrance so that parents and visitors could be immediately greeted, and the administrative suite, which included the principal's office, was to the left of the reception area.

A set of double doors leading to the school's main hallway (H1) was to the left of the reception area. This hallway was at the front of the building, and a hallway parallel to this one (H2) was at the back of the building. Three vertical hallways (V1, V2, and V3) connected the H1 and H2. Classrooms were on both sides of each hallway. The school's small gymnasium was near the entrance of H1, and the most of the classrooms for juniors and seniors were also along H1. George's classroom was on the right side of H1 near the end. The faculty parking lot was accessible through an exit on the left side of H2, and Mary's room was near this exit. In addition, HHS also had several "portables," or trailers in which classes were held, at the end of the faculty parking lot. Freshmen classes were primarily held in the portables. Jessica's classes were held in a portable.

Hopewell High School is a “Title I” school, meaning the school receives federal funding. Title I status is determined based on the percentage of the student population from low-income families (in addition to a few other factors). Title I funds are issued to assist “students at risk of not graduating” become proficient, according to their states, through the implementation of school-wide tutoring or assistance programs, with the ultimate goal of increasing student graduation rates. During the 2011−2012 academic term, there were approximately 1,310 students at HHS: 96% of the students were African American and 2% were Hispanic; nearly 80% of the students were eligible for free or reduced-price lunches. The school followed a comprehensive educational program that included a variety of elective subjects in addition to the core areas of study. There was a host of other activities for the students at HHs, including a student government association, academic competitions, community service opportunities, and several special interest organizations. Hopewell also had team and individual sports such as football, volleyball, basketball, track, and tennis.

No Child Left Behind legislation requires that all schools receiving Title I funds make Adequate Yearly Progress (AYP), which is determined by each State. These State-set student achievement goals are based on student population, demographic factors, and economic status. The schools that fail to meet AYP targets for over two years are designated as schools in need of improvement. During the time of the study, HHS was in “Needs Improvement” status for the third consecutive year. During the year 2011-2012, HHS had met the AYP in two areas, test preparation and academic performance; however, AYP criteria for graduation rate had not been met.

The Survey Instrument and Scoring Process

The survey used to collect data during this study consisted of 25 statements that belonged to one of three categories: problem solving, students and PBL, and designing PBL problems (Appendix A). The survey was administered to study-participants at three intervals: (1) The "initial survey" was administered on the first day of the week-long PBL academic session in the summer of 2011. This was the first day of the 2-year project, and this survey was issued prior to the participants being introduced to PBL. (2) The "midpoint survey" was administered on the last day of the weeklong PBL academic session. (3) The "final survey" was administered in the spring of 2012 during the last session of the first year of the project. Upon completion, each survey was scored, and this score was calculated based on responses to the statements. Survey statements were either "positive" statements or "negative" statements.

The following points were given for positive statements: strongly agree = 5 points; agree = 4 points; neutral = 3 points; disagree = 2 points; and strongly disagree = 1 point. So if a participant "disagreed" with a positive statement, 2 points were given. The points assigned were reversed for negative statements: strongly agree = 1 point; agree = 2 points; neutral = 3 points; disagree = 4 points; and strongly disagree = 5 points. So if a participant "agreed" with a negative statement, 2 points were given.

Problem-Solving Category

The problem-solving category was worth a total of 45 points, and participants' self-reported scores represented their beliefs about the constructivist principles of problem solving supported by PBL. A ranking scheme was constructed to categorize each participant in terms of his or her responses to problem-solving statements that are characteristic of PBL. Survey scores ranging from 36 to 45 points represented a participant's high level of agreement with problem-solving statements characteristic of PBL; a range from 27 to 35 points represented intermediary agreement; a range from 18 to 26 points represented an intermediary disagreement, and a range from 9 to 17 points represented a high level of disagreement.

Students and Problem-Based Learning

The students and PBL category was worth a total of 50 points, and participants' self-reported scores represented their beliefs related to student characteristics in a PBL setting (according to claims by Savery & Duffy, 2001). Participants were ranked based on how they rated themselves in this category. Their self-reported scores with total number of points between 40 and 50 represented a high level of agreement, a range from 30 to 39 represented intermediary agreement, a range from 20 to 29 represented intermediary disagreement, and a range from 10 to 19 represented a high level of disagreement.

Designing Problems for Problem-Based Learning

The final category, designing PBL, was worth a total of 30 points, and participants' ratings represented participants' beliefs related to their own level of readiness to design PBL problems both appropriate for their students and related to the Common Core Standards. In this category, a score ranging from 24 to 30 represented a high level of readiness, a range from 18 to 23 represented an intermediary high level of readiness, a range from 12 to 17 represented an intermediary low level of readiness, and a range from 6 to 11 represented a low level of readiness.

Introduction of the Study-Participants

All of the study participants, Jessica, Mary, and George, were mathematics teachers at HHS. Jessica has both a Master's and a Bachelor's degree in mathematics. She taught beginner's mathematics courses at her graduate institution for some time and later moved on to teaching high school mathematics. At the time of the study, Jessica had been teaching for 19 years and was currently teaching Integrated Advanced Algebra for high school freshmen. Mary has a Bachelor's degree in mathematics and was working on her Master's degree at the time of the study. She had been teaching for 22 years and was currently teaching Integrated Advanced Algebra and Accelerated Integrated Advanced Algebra for high school freshmen. George was the mathematics department chair at HHS. He had a Master's degree in mathematics and had been teaching for 31 years. As the department chair, George had to conduct weekly meetings, plan professional learning committee (PLC) activities, and address the needs of the teachers in his department. During the time of the study, George was teaching Math III and Advanced Placement Calculus at his school.

After concluding the summer 2011 academic session, in the beginning of fall 2011, the study-participants' were given somewhat modified job responsibilities. Some of these changes were the result of teachers being transferred as well as teacher resignations. These unexpected changes had effects on study-participants responsibilities and this delayed the process of implementing PBL by the study-participants in their classrooms. A timeline of participant activities is presented in Table 2.

Table 2

Timeline of Participant Activities

Time period	Jessica	Mary	George
Summer 2011	Attended PSPBL; created a PBL along with the team of ninth grade teachers	Attended PSPBL; created a PBL along with the team of ninth grade teachers	Attended PSPBL; worked on creating a PBL
Fall 2011	Assumed new duties as 9th-grade team leader; discussed implementing PBL	Assumed new duties as 10th-grade team leader; got analytical geometry teaching responsibilities instead of advanced algebra; discussed implementing PBL	Implemented the *Starbucks gift card* PBL for a 2-week period along with the typical teaching and learning duties
Spring 2012	Implemented PBL as a substitute for final exam during the last 7 days of school	Implemented PBL as a substitute for final exam during the last 7 days of school	Discussed implementing another PBL

Within-Case Analysis of the Changes in Teacher Beliefs

In this section, I analyze the a) participants' changes in beliefs about mathematics teaching and learning, b) participants' changes in instructional practice, c) participants' challenges in designing and implementing PBL, which were evidenced during participant interviews. I also examine the above using the participants' three survey results, which had been administered at three different time points throughout the study. In addition, I utilized the participants' reflective journal entries that had been recorded concluding each day of the weeklong PBL academic session. During the interview, participants shared students' behavior and attitude during PBL implementation. I have also analyzed the data on students' behavior and attitude in this section.

Changes in Teacher Beliefs on Teaching and Learning Mathematics

Jessica. During the summer of 2011, Jessica shared her first thoughts on PBL in her journal entry. On the first day of the "Project Success in Problem Based Learning" (PSPBL) academic session, teacher-participants worked in groups and solved a problem from a PBL case known as the "Starbucks Gift Card" (SGC) case (Appendix B). Different groups made different assumptions, utilized different methods to solve the problem and produced different results. In a journal entry, Jessica expressed that her experience solving the SGC case made her realize that there was more emphasis on the process of solving the problem than there was on the solution to the problem. She found the problem completely engaging, stating that solving the problem required critical thinking. She also indicated in this journal entry her belief that PBL would serve as a hook to students and get them involved in the learning process. Under teacher-directed instruction, students struggle to understand the concepts without the "hook." Jessica's journal entry also reflected her thoughts on transitioning from the teacher as "a giver of information" to the teacher as "coach." Jessica added that this change in roles was quite the challenge and would require a new way of thinking. At the end of PBL academic session, she indicated in a conversation with me that she was determined to implement PBL in her classroom.

During the PSPBL academic session, Jessica and Mary along with several other teachers collaboratively created a PBL, 'Will you miss the i-Call?' on logo design using graphs of basic functions and their transformations. However, some of the teachers on this team did not return to HHS when school had resumed in the fall of 2011. Jessica, as the team lead had the responsibility to have all teachers follow the same curriculum in all of their algebra classes and increase the End-of-Course Test (EOCT) scores. This made Jessica to decide to implement the PBL case after completion of the EOCT. An EOCT is a state mandated assessment for core classes that provides data to evaluate the effectiveness of classroom instructions at the school and also helps in improving student performance.

Jessica confided that she was not confident in providing students with opportunities to solve problems through inquiry although she had disagreed with the statement, “Problem solving in any topic in mathematics should be done after teaching the concept in great detail” on her initial, midpoint, and final surveys. As a general practice, Jessica allowed her students to solve problems only after teaching the concepts in great detail. She remarked that her freshmen students lacked the required skills and maturity to think through problems and solve them without step-by-step instructions. Jessica commented that the sophomore students at HHS were relatively more mature and ready to solve PBL cases based on her understanding of her colleagues’ teaching practices. During the interview, Jessica quoted as follows:

> I felt like this group—the 10th-grade group—was more ready for a PBL structure. I think the maturity was there to handle PBL. But I don’t think I feel the same way with my 9th-grade group coming in this year; I don’t think it is going to be as hands off with this group—maybe the second semester one but for the first semester, I noticed that they may need a little bit more guidance. As far as the PBL is concerned, I may let them start something, then take a day and teach something, and then let them resume the PBL on another following day or another following week—try to scaffold, allowing more freedom at a later time.

When assigning PBL cases, teachers might have to first scaffold the problem with direct instructions and give students the freedom to use various strategies at the end.

Jessica disagreed with the survey statement; “Students learn to solve varied problems by repeating the same procedure again and again.” She did not want to be the teacher that gave students procedures and solution types, and then expecting the students to rehearse and practice. According to Jessica, learning by practice cannot be sustained. In her interview, she remarked:

> I don’t know if learning by repetition is good towards sustained learning. To me, it might just be temporary: for the moment, for the test. And if you are a true educator, you don’t want it to just be something that they just learn for the moment, for the test. You want it

> to be something that is sustained over a few years and into the next course so that the next teacher that gets them is not saying, 'Didn't that teacher teach that concept last year or two years ago?' So in that case, I like things to be more sustained; I don't want it to be kind of, 'I give it to you; you just do a rehearsal of... This is what the problem looks like; this is how the answer should be...' I would like a little bit more depth.

Jessica remained neutral to the survey statement, "Ill-structured problems are more effective in terms of deeper understanding," on her initial survey, agreed on her midpoint survey, and was again neutral on her final survey. During her interview, she stated that she was not clear what "ill-structured problems" referred to during the initial survey, but that her experiences during the PBL academic sessions provided clarity. After understanding what ill-structured problems were, Jessica agreed with the statement. During the interview, Jessica agreed that such problems can be effective means of helping students understand mathematics. However, she also shared that creating ill-structured problems for PBL cases can be quite challenging, and she did not consider herself competent enough to design these problems. As Jessica said, students retain information when they conduct the required research to solve ill-structured problems.

Jessica agreed with the survey statement, "Students understand better when solving problems with a unique solution," on her initial survey, disagreed on the midpoint survey, and agreed again on the final survey. She complained that nearly 40% of her incoming 9th graders do not pass the State-administered Criterion Referenced Competency Tests (CRCTs) in 8th grade. To teach her students, Jessica reported the need to reach them where they are by providing them with problems that have unique solutions to enhance their performance on the assessments. Jessica stated:

> The different standardized tests they are taking are very important because that's how I am looked at as a teacher: I am evaluated as a teacher; my data goes up for everybody to see. I do like the idea of PBL and open-ended problems so that the kids will seek (to learn) further—they won't just wait on me. They want to seek it out for themselves, kind of like what I said. Kids will come to me as the last resort. They tried to search out or shall I say seek out the right answers, so that part of PBL, I do agree. It takes the child to,

> I guess, to want to go further or ask, 'Why does it do this?' That right there develops more of an intuitive mind, especially when it comes to math. Kids are having a lot of challenges in math; I think it is great that they start questioning more.

Jessica did not strongly agree or strongly disagree with any of the survey statements, but she consistently agreed with the following two positive statements: (1) "Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards" and (2) "Solving complex problems as a group helps students to learn different ways of solving the same problem." She also disagreed with the following five negative statements: (1) "Students should not be given freedom to utilize different strategies while solving a problem." (2) "Students learn to solve varied problems by repeating the same procedure again and again." (3) "Problem solving in any topic in mathematics should be done after teaching the concept in great detail." (4) "When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution." and (5) "Students cannot be responsible for their learning; they have to depend on their teachers."

Jessica agreed with the negative statement, "Students understand better when solving problems with a unique solution." Even though Jessica believed in the effectiveness of open-ended problems with multiple solutions, her focus on preparing students for the EOCT inhibited her from providing opportunities to students involving solving problems with multiple solutions. During her interview, she mentioned that her school district emphasizes EOCT score improvement. Hence, Jessica prioritized helping students get higher EOCT scores over PBL implementation.

Jessica's total numbers of points in the problem-solving category were 33 of 45 on the initial survey, 36 of 45 on the midpoint survey, and 33 of 45 on the final surveys (see Appendix C). Her midpoint survey ratings are within the "high level agreement" range for problem-solving statements that reflect the characteristics of PBL. Her initial and final survey ratings fall within the "intermediary high level of agreement" range. Jessica's movement toward "high level of agreement" from the initial survey to the midpoint survey was not sustained. Jessica's self-reported total numbers of points on statements related to the teaching and learning of mathematics in the problem-solving category are exhibited in Figure 2.

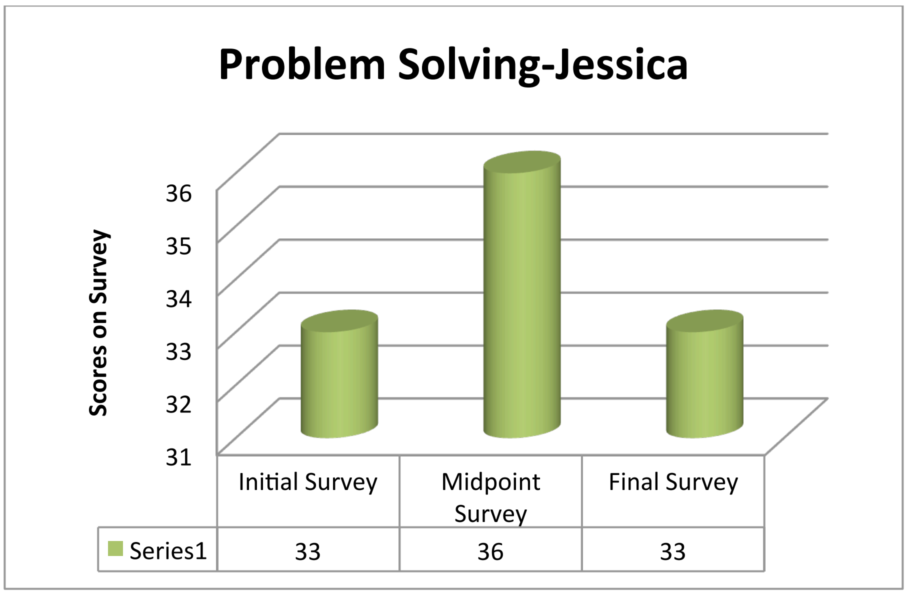

Figure 2. Jessica's Total Survey Points Related to Teaching and Learning Mathematics.

Mary. Mary's first journal entry, which was written concluding the first day of the PSPBL session, reflected that she enjoyed the challenges of solving the Starbucks gift card (SGC) case. However, Mary expressed concern that low-performing students may lack the persistence required to solve PBL cases and that these students may get confused and frustrated. In addition, Mary stressed in her journal that she was concerned with her students' ability to adapt to PBL and respond to it positively. In her journal she had stated, 'I am mostly afraid of my students response. They are not always good with change and might be frustrated easily'.

Mary agreed with the survey statement, "Students learn to solve varied problems by repeating the same procedure again and again" on her initial survey, but she disagreed with the same statement on the midpoint and final surveys. During her interview, she explicitly described her beliefs in “drills,” emphasizing that drills should not be taken away:

> I know the trend is to go away from *drill*. However, I do not always agree with getting rid of drill; some drill needs to stay. For example, they did away with learning timetables, so now the kids cannot multiply, they struggle on a whole bunch of concepts that follow, and they lose math sense.

Mary believes that her students should have the conceptual understanding and procedural knowledge needed to solve problems, stating that the repeated practice of solving problems helps students to find “cue words” that might help them with problem solving. According to Mary, students have difficulties solving word problems because they lack the required reading and comprehension skills. She feels that drills help students find cue words, thus drills help students comprehend a problem.

Mary remained neutral to the survey statement, “Ill-structured problems are more effective in terms of deeper understanding,” on her initial survey, but she agreed to this statement on her midpoint and final surveys. During her interview with me, Mary stated that she initially had difficulty understanding what “ill-structured” referred to. However, she got more comfortable and confident working with ill-structured problems near the end of the PBL academic session. Mary described ill-structured problems as “questions/problems that are not asked as direct questions, but questions that are distorted.” Mary expressed that she would like to use ill-structured problems regularly in her classroom, emphasizing that she was making efforts. During the interview, she admitted that she was not sure of the statement referring to ill-structured problems being effective in terms of aiding a deeper student understanding, as her experience with ill-structured problems was limited. Mary believed that her high-performing students are able to utilize prior knowledge and “trial and error” to discover new concepts. Naturally, ill-structured problems foster a deeper understanding as well as information retention.

However, Mary indicated that her low-performing students “shut down” when asked to solve problems that require trial and error, as these students lack the basic skills needed to establish connections between prior knowledge and new concepts. Therefore, while ill-structured problems may be good for high performers, they do not work for low performers. According to Mary, discovery helps all students; however, low performers may be unable to apply their discoveries to new situations.

Mary disagreed with the statement, “Problem solving in any topic in mathematics should be done after teaching the concept in great detail,” on the initial survey, strongly agreed on the midpoint survey, and remained neutral on the final survey. During the interview, Mary commented that some mathematics concepts are interesting enough for students to study on their own and solve using the information provided as well as discovery. In such cases, students might discover something incorrectly, but this can be clarified through proper questioning. Yet Mary reported that certain mathematics concepts are too difficult to learn via discovery and that solving problems for these more challenging concepts is possible only after the students have learned the concept.

Mary strongly agreed with the survey statement, “Students understand better when solving problems with a unique solution,” on the initial and midpoint surveys and just agreed on the final survey. She opined that students might learn better when solving problems with multiple solutions in a perfect world where students are *thinkers*. However, Mary remarked that she would lose her students if she attempted to teach them problems with multiple solutions in multiple ways. According to Mary, if students are taught to solve problems in multiple ways, they will attempt to use all methods at once and will reach an inaccurate solution. Mary believed that the students’ level of understanding is what dictates teaching methods. Mary also placed some of the blame for teachers not being able to teach students how to solve problems with multiple solutions on standardized testing standards. Mary stated that students are expected to work toward the single correct answer on standardized tests, so she does not want her students bogged down with multiple-solution problems. Mary mentioned that it was scary to teach something in class that may not be utilized during standardized testing time, and she did not want her students to be "lost" when it was testing time. She asserted that she liked the idea of PBL cases where problems had multiple solutions, but she was apprehensive of the fact that PBL had no bearing on standardized testing. Mary believed that PBL cases helped students extend their learning beyond the classroom and be more prepared for college. However, she said that PBL has to be supplemental, as students must be taught to solve problems with unique solutions.

Mary agreed with the statement, "Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards," on the initial and midpoint surveys and strongly agreed on the final survey. However, Mary disagreed that, "Students should not be given freedom to utilize different strategies while solving a problem," on the initial and midpoint surveys and strongly disagreed with this statement on the final survey, increasing her overall rating. She strongly agreed with the statement, "Solving complex problems as a group helps students to learn different ways of solving the same problem," on the initial and midpoint surveys and agreed to the same on the final survey, decreasing her overall ratings.

Mary strongly disagreed with the following two negative statements: (1) "Students cannot be responsible for their learning; they have to depend on their teachers," and (2) "When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution." On the final survey, Mary had strong beliefs about four statements and remained neutral to only one statement, “Problem solving in any topic in mathematics should be done after teaching the concept in great detail,” indicating that this statement could be true or false depending on students’ performance levels. Mary received the fewest numbers of points for agreeing with the statement, “Students understand better when solving problems with a unique solution,” and she mentioned that her beliefs stem from the fact that on the EOCT, students have to solve problems with unique solutions. Mary’s responses in the problem-solving category were 33 of 45 on the initial survey, 32 of 45 on the midpoint survey, and 37 of 45 on the final survey (see Appendix D). Mary’s self-reported ratings on the initial and midpoint surveys fall in the “high intermediary level of agreement” range in the area of problem solving reflecting PBL characteristics. Her ratings on the final survey are categorized as “high level of agreement” in the area of problem solving statements indicating a slight change in her beliefs on teaching and learning of mathematics. The total number of points Mary earned on statements related to the teaching and learning of mathematics in the problem-solving category are exhibited in Figure 3.

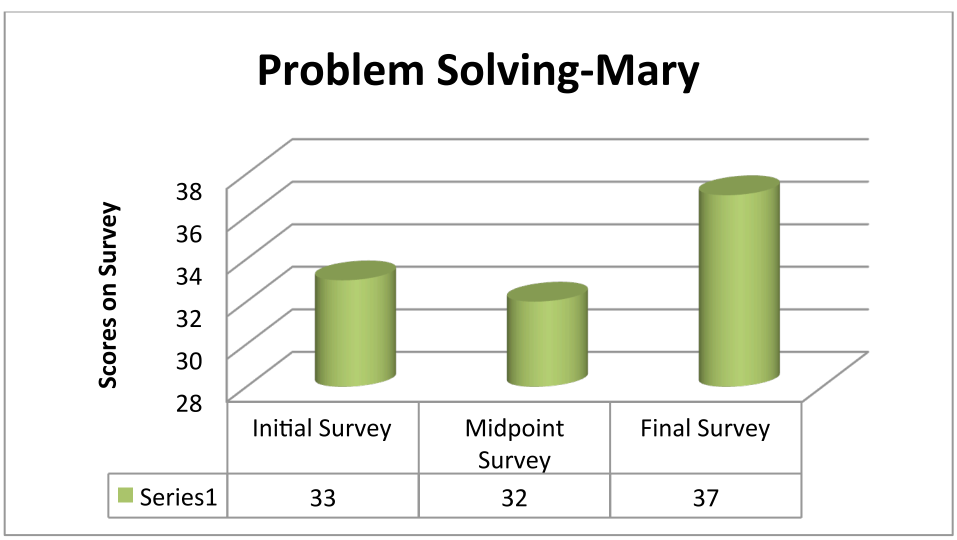

Figure 3. Mary’s Total Survey Points Related to Teaching and Learning Mathematics.

George. George, in his first journal entry wrote that PBL helped teachers motivate their students to learn through the use of effective techniques. In another journal entry written during the same PSPBL academic session, George mentioned that it was difficult to design PBL cases and also that he was not prepared to implement PBL in his classroom. However, he was the first of the three participants to actually implement PBL case in the classroom. George started planning for his PBL immediately after the PSPBL academic sessions and implemented his PBL in the month of October in the first semester. In the problem-solving area of the survey reflecting statements related to mathematics teaching and learning, as based on PBL's constructivist principles, George's beliefs on at least four of the survey statements were unchanged. George agreed with the positive statement, "Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards," in his initial, midpoint, and final surveys. However, George has never collaborated with a science teacher at his school.

George also consistently agreed with both of the following statements: (1) "Solving complex problems as a group helps students to learn different ways of solving the same problem," and (2) "Ill-structured problems are more effective in terms of deeper understanding." During his interview, George stated that ill-structured problems enabled a deeper understanding of the concept because they allow students to formulate effective solutions by applying their prior knowledge about the problem without guidance. George compared these problems to puzzles, saying that understanding ill-structured problems is equivalent to solving a puzzle. George deemed it necessary for teachers to monitor their students while they attempt to solve ill-structured problems, so that students do not feel lost, discouraged, or unsupported.

George disagreed with the statement that "Students understand better when solving problems with a unique solution" in his initial survey, he remained neutral in his midpoint survey, and he disagreed again in the final survey. During the interview, George asserted that students learn better when solving problems that have multiple solutions. He consistently remained neutral to the statement, "Students should not be given freedom to utilize different strategies while solving a problem" in his initial, midpoint, and final surveys. However, during the interview, he favored students' use of multiple strategies to solve problems. According to George, using multiple strategies to solve problems is more beneficial because it facilitates a better understanding of the problem. When multiple strategies are available, students must go through the mental processes of choosing the appropriate strategy for the given scenario, which gives more insight into the situation. George used the analogy of a painter painting a door: A good painter will choose a smaller brush for the job even though it seems that a bigger brush would get the job done more quickly. According to George, when solving a problem, it is important to find the strategy best suited for the given situation.

George disagreed with the negative statement, "Students learn to solve varied problems by repeating the same procedure again and again," on the initial and midpoint surveys, rating 4 points for each; however, George agreed with this statement on the final survey, rating only 2 points. George clarified during the interview that while he disagreed with the statement in general, he also believed that students with low levels of mathematics achievement need repetition to build their confidence. George believed that students learn by consistently solving different types of problems because he considered problem solving a skill, not a procedure that can be memorized.

George followed the same pattern, from disagreement to agreement, for the negative statement, "When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution." He disagreed with this statement on the initial and midpoint surveys, rating 4 points for each. However, on the final survey, he agreed, scoring only 2 points. George also disagreed with the negative statement, "Students cannot be responsible for their learning; they have to depend on their teachers," on the initial and midpoint surveys, scoring 4 points for each. He gave a neutral response to this statement on the final survey. George agreed with the negative statement, "Problem solving in any topic in mathematics should be done after teaching the concept in great detail," on the initial and final surveys; he remained neutral on the midpoint survey. During the interview, George discussed his disagreement:

> No, I do not agree. I think problem solving can be actually taught before teaching the standard. I think problem solving can be taught before actually teaching details. I think students do have an innate ability to understand problems, concepts, and formulas through trial and discovering. However, I do think that facilitation is necessary, and guidance is necessary.

George's responses in the problem-solving category were 31 of 45 on the initial survey, 33 of 45 on the midpoint survey, and 26 of 45 on the final survey (see Appendix E). His ratings on the initial and midpoint surveys fall in the "intermediary level of agreement" range in problem solving statements reflecting PBL characteristics. George's final survey ratings are within the "intermediary level of disagreement" range. The shift from intermediary agreement to intermediary disagreement stems from George's disagreement with four statements reflecting PBL characteristics on the final survey. George's scores for belief statements related to mathematics teaching and learning in the problem-solving category are presented in Figure 4.

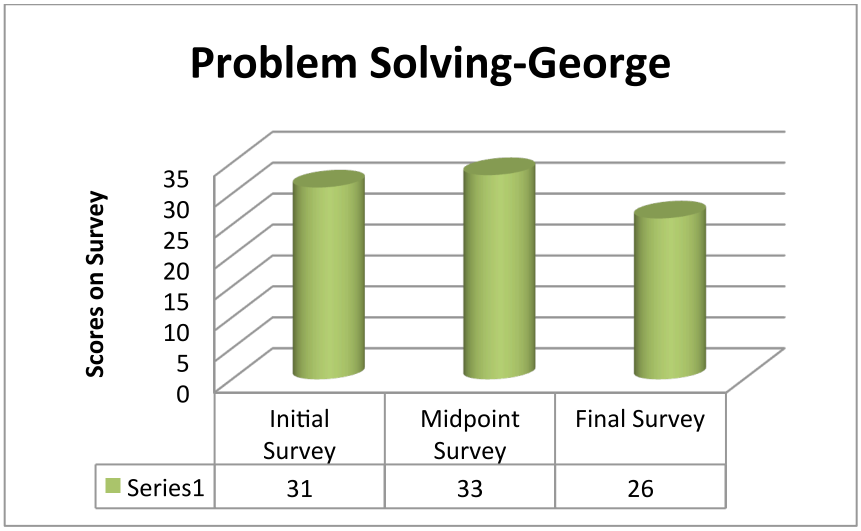

Figure 4. George's Total Survey Points Related to Teaching and Learning Mathematics.

Changes in Instructional Practices

Jessica. According to Jessica, professional development sessions helped her move away from traditional teaching. Jessica stated that traditional teaching represented classroom processes that including direct instruction, student listening, guided practice, and independent practice. During the interview, Jessica mentioned that the first PBL case she implemented helped her embrace a more student-centered approach in her classroom. During PBL implementation, Jessica noticed that her students interacted more, solved their mathematical problems, and clarified their misconceptions within the group prior to approaching her. Jessica even stated that she was waiting for students to approach her perhaps for technical support with the calculator or help with functions, only to realize that they were consulting each other and only approaching her when they were completely lost.

Jessica acknowledged that she was more apprehensive about implementing PBL in her algebra class after the first academic session on PBL because she missed her team of teachers that had assisted in the design the PBL. As stated earlier, some of the teachers from her ninth grade team did not return to HHS in fall of 2011 after the PSPBL academic sessions. However, implementing a PBL along with the team of geometry teachers in her geometry class had given her the confidence to design and implement a PBL in her algebra class, as well. During the interview, Jessica communicated her beliefs that PBL could be more impactful in increasing EOCT scores. She stated that she had started facilitating inquiry in class without giving too much information, especially during after-school and Saturday tutorials. Jessica stated:

> I think my thought process of not just lecturing and allowing kids to inquire more kind of happened within the classroom day to day. I think I was doing that more even when I worked with kids on Saturdays, as we did the EOCT preps, after-school tutorials. I saw myself letting go more—always have been one of the traditional (type). I might show you how to do it—you got to do this formula, you got to do this way—but now, I allowed kids to show me certain things, and then I can say, 'Yeah, that works,' or I would have to say, 'Nay, I don't know if it's going to work every single time.' So I think it allowed me some change as far as comparing from last summer to this summer (interview).

Mary. Mary acknowledged that the PBL academic session changed the way she used questioning in her class. During the interview, Mary mentioned that even though she does not use PBL as often as she would like, she has been using the questioning and scaffolding characteristics of PBL that make the teacher a facilitator. According to Mary, she begins her class with a real-life problem or question as a "hook" to capture her students' interest. Mary said she encourages her students to interact with each other and begins the conversation before introducing the day's topic. Mary states that she responds to students' questions with a question that makes students think instead of giving them direct answers. Mary recognized that the two PBL academic sessions affected her thought processes and brought changes to her instructional practices and her style of questioning. Mary said that she was implementing different teaching and learning strategies such as cooperative learning, various methods of student assessments other than paper-and-pencil tests, and the use of technology (including geometer's sketchpad).

As Mary stated:

> The two academic sessions did affect my way of thinking. It has brought about changes in my way of questioning; PBL is in my vocabulary now. I talk about it all the time. Even today, I met a teacher from another county, and I was asking her if she had done PBLs in her class. I am enrolled in school now. We have discussion boards, and I write about PBLs on those. PBL is in my system. Teaching itself has been evolving, students are changing, the world's system is changing, so you have to change anyway. What worked in 1920 doesn't work now. What worked when I started teaching 23 years ago doesn't work now. Most definitely, I have made some changes; I'm excited about the different strategies I'm being taught to make the transition, and I'm trying to use them (interview).

Mary stated that while designing regular group work in class, she tries to give her students opportunities to make discoveries and talk through their problems. She owes her changes in attitude to PBL implementation while admitting that her group assignment is not very close to an authentic PBL problem. Mary also indicated that she has started to lecture less and encourage more student participation. In addition, Mary acknowledged that the PBL academic sessions and other professional development sessions she has attended have made her reflect more, made her more willing to change, and shown her that she is not as stubborn as she was.

George. George did not provide direct or indirect comments during his interview about his instructional practices in his classroom. Although I did visit George's classroom once on the first day of his PBL implementation and during his planning periods and other times, there is not enough data to discuss changes in his instructional practices.

Challenges in Designing and Implementing PBL in the Mathematics Classroom

Jessica. Jessica wrote, in a journal entry, that she was excited about the PBL case that she and several other algebra teachers had created during the PSPBL academic sessions, "Will you miss the i-Call?" and that she had planned to use this case in her classroom in the fall of 2011. However, upon her return to school that fall, she discovered that she had been assigned the new role of lead algebra teacher, which meant that she was now responsible for increasing the percentage of students passing the Algebra EOCT. During my first visit to HHS during the fall 2011 term, I noticed that several members from the team of algebra teachers that had created the i-Call PBL case during the PSPBL session were either teaching other subjects or no longer at the school. Jessica now had to work with teachers who had not attended the PBL academic session, and she also had to ensure that all teachers on her team were following the same curriculum throughout the academic year. Jessica informed me that she did was not comfortable implementing the PBL case on her own, nor was she comfortable asking teachers with no PBL experience to implement the case in their classrooms. According to Jessica, she was focused on the EOCT and getting the other team teachers on board with her. Jessica acknowledged that her department head had encouraged her to implement PBL during the first semester; however, she had decided to implement a PBL case during second semester in her singleton geometry class she was teaching because the teachers from the geometry team had already collaboratively planned their own PBL activities.

Jessica identified the biggest challenge with the use of PBL as creating an ill-structured problem that is relevant to the real world, open-ended, and can be solved in multiple ways. During the interview, Jessica commented that understanding the new standards defined by the recently introduced common core standards and then aligning certain concepts to these standards was quite the challenge because it was hard for her to create a pacing guide for the course for the two semesters. Under these circumstances, according to Jessica, it was problematic for her to create scenarios that were intriguing and engaging enough to "hook" the students. Jessica believed that collaborative team planning enables teachers to share ideas to design authentic PBL cases. She remained neutral to the statement, "Ill-structured problems can be easily designed to incorporate any mathematical and science topic," and agreed with the negative statement, “Content knowledge in the subject area is not necessary to design PBL cases pertaining to standards appropriate for students.” She agreed with the following two positive statements: “Designing PBL cases pertaining to standards and appropriate for students is challenging but possible,” and “Real world and open-ended problems in science can be easily designed.” Jessica scored 21 of 30 points on the final survey in the “designing PBL cases” category (see Appendix F). This score represents an intermediary high level of readiness to design and implement PBL cases in the classroom.

Mary. Mary noted that she finds it difficult to create PBL cases due to the conflicting requirements of the PBL case being an authentic scenario that can occur in the real world that is also appealing to the students. Incorporating the standards into the real-world problem is comparatively easy; however, designing both an ill-structured and appealing problem is difficult, Mary described. Mary also expressed some anxiety about the language used in the scenario, sharing that students were critical of the language used in the PBL scenarios and called the problems “pathetic” because she appeared to be making a poor attempt to “sound like them” when she really could not. According to Mary, the most difficult element of PBL is creating a problem that is concise and creative and still addresses the desired common core standard to be taught.

At the time of PSPBL academic session, Mary was the lead teacher for 9th-grade algebra. During the first PSPBL session on PBL, Mary expressed her excitement about PBL in her journal. During the session, Mary and the rest of the teachers on her team created a PBL case for 9th-grade algebra students, which went through several rounds of editing. However, when Mary returned to school for the fall semester, she was assigned to 10th-grade geometry. Mary conveyed that she was disappointed and that the change was somewhat disrupting. During one of my visits to HHS, Mary pointed out that it took her time to learn the new curriculum and plan to teach this "her way." Mary said that she did not want to implement a new PBL case until she was first comfortable with the new curriculum. To Mary, EOCT did not take precedence over PBL, but it was definitely a precursor. Ultimately, Mary wanted to be proficient in teaching geometry before she attempted to use PBL in her classroom.

Mary agreed with the following statements: "Designing PBL cases pertaining to standards and appropriate for students is challenging but possible," and "Real world and open ended problems in science can be easily designed." She strongly agreed that, "Ill-structured problems can be easily designed to incorporate any mathematical and science topic." She either disagreed or strongly disagreed with negative statements related to designing PBL cases, stating that real-world, open-ended mathematics problems and problems that are interesting to students cannot be easily designed. Mary scored 27 of 30 possible points on the final survey in the "designing PBL cases" category (see Appendix G). This score represents a high level of readiness in terms of designing and implementing PBL cases for the classroom.

George. When George was asked a question during the interview about designing and implementing PBL cases, he started by saying that he would like to spend more time creating PBL cases that could be introduced as supplemental resources for the curriculum he taught. However, he quickly modified this view by saying that designing a PBL case was time-consuming and that teachers never have the time required to even consider developing a PBL case. George expressed that either curriculum personnel or some other publishers should be the ones responsible for designing PBL cases, not teachers. During the interview, George spoke at length about designing PBL cases, indicating that they should be aligned with the standards, they should be interdisciplinary, and they should also be tested for student engagement and bias.

According to George, there have been so many curriculum changes over the past several years and so many changes in teaching strategies and teachers' responsibilities that teachers lack the time they need to simply reflect and tap into their own past experiences.

George explained what he meant by bias, stating that the PBL cases designed should be engaging for all students. George did not want PBL cases that targeted only some of the students due to their exposure. He elaborated by saying that students that have never visited a mall are not likely to be interested in a PBL case related to shopping experiences and that students that have never played cards may not be interested in a case about card games. Hence, according to George, the job of developing PBL scenarios that are aligned with standards and students' ability levels, testing these scenarios for bias, and revising these scenarios must be done by a team of experts, possibly retired veteran teachers, or publishers because teachers have more responsibilities than just instructional planning. George added that even if a good PBL case is created, finding the time to use the case in the classroom is still a challenge.

George stated that it took him some time after the initial PBL academic session to fully understand PBL and feel comfortable designing PBL cases for his students. He said that even though he had implemented a PBL case that was not created by him, he was confident in his ability to create one but simply lacked the time to do so. In terms of PBL implementation, George expressed that he was comfortable extending the case over time and also giving his students direction on the topic. George mentioned that although he realized that PBL cases must be developed before the related concept was introduced, he would have to wait to move in that direction until after implementing one or two PBL cases.

George agreed with only one statement on all of the initial, midpoint and final surveys, "Designing a PBL case pertaining to standards and appropriate for students is challenging but possible." He was neutral to the following two statements on the final survey: "Real world and open ended problems in science can be easily designed," and "Ill- structured problems can be easily designed to incorporate any mathematical and science topic." In the final survey, George either agreed or strongly agreed with the negative statements on designing PBL cases, such as, "Real world open ended problems in mathematics and problems relating to students' interests cannot be easily designed." In addition, George did not disagree with the negative statement pertaining to content knowledge in the subject being unnecessary to design a PBL case. Thus, George earned only 15 of 30 possible points on the final survey for the "designing PBL cases" category (see Appendix H). This score indicates a low intermediary level of George's readiness to design and implement PBL in the classroom.

Students' Behavior and Attitudes during PBL

Jessica. After implementing PBL for the first time as a final assessment in her geometry class, Jessica shared her excitement during the PSPBL II session in the summer of 2012. Jessica remarked that she wished she had implemented PBL at the beginning of the school year using a topic that was both interesting and engaging for the students. Jessica's PBL case required that students use functions to design a logo for their product of choice and later produce the same logo using a graphing calculator with restricted domain. Finally, students had to create a neatly drawn poster of the logo and perform a skit explaining the logo and promoting their product.

Jessica and Mary used the same PBL case in their classes at the same time, both during the last two weeks before summer holidays. During Jessica's interview, she mentioned that on the days of PBL implementation, her students tried hard to be present and on time for class and when they had to miss a day, they would bring notes from their parents requesting that the absence is excused, which was quite uncommon. Jessica considers her students' ownership of the

PBL case a great success in PBL. On PBL class days, Jessica allowed her students to create group rules, and the students created rules similar to the classroom rules that already existed. During the interview, Jessica shared:

> During the two weeks of PBL implementation, students were eager to be in class, students reported on time to class, and made sure that all supplies including graphing calculators were ready. Absenteeism and tardiness were minimum; only 2 students missed 2 days, and 1 student missed a day. Students utilized the entire 52 minutes of class time working on creating their logo design and creating their commercial. They did not tolerate any kind of misbehavior from other group members and made sure everyone was on task throughout the class period.

Jessica expressed satisfaction with the groups she had created during PBL implementation. She mentioned that her students were engaging in an experience for the first time: the teacher was not up front lecturing, giving notes, and guiding students through practice problems, and all of the students were able to use their strengths and talents. Jessica noted her observation that the most creative person in the group took responsibility for the commercial/skit and helped create the poster while the more academically advanced students were responsible for transferring the logo using functions. Although some of the students were using the graphing calculators for the first time, they were anxious to learn how to change the window, change the scales, etc. These students also explained the mathematical concepts behind the logo to other group member. Jessica stated:

> We saw some good things; those students who were not good in math did participate well; they felt that even though they did not have good math skills, they had other strengths that could be utilized in the presentation. There were some artists, some performers, who participated with enthusiasm in the final presentation. Also, I felt as a teacher, I was inadequate. I also saw eagerness in them, the curiosity to learn and complete the presentation. Even though we had given 7 days to complete the end product, they were too eager to complete, and when they entered the class, they would complain about me not being ready. They would say that I did not get their calculators set up for them.

Jessica explained that her feelings of inadequacy emerged from the fact that whenever her students had a question or needed clarification they consulted with each other and went to Jessica only if they could not find answers on their own.

Mary. When I visited HHS in the spring of 2012, I gathered that Mary, as the geometry team lead, took the initiative to define the day-to-day activities that would occur during PBL implementation (see Appendix I). Their PBL case was a modified version of the case that had been designed for the 9th-grade algebra class. This PBL required that students to create a logo for an imaginary product and company using a graphing calculator. Students also had to develop an advertisement skit and relate the logo to the product. During the interview, Mary shared that she was fascinated with the events that occurred during PBL implementation. Mary further remarked that the students were excited because they did not have to take a paper-and-pencil test involving multiple-choice problems, but only had to complete the PBL case. Student assessment occurred on a daily basis (see Appendix I) for the collaborative portion, and the skit and finished product were assessed on the final day of the presentation. Mary informed that students were concerned about losing points for being absent, so they tried to be present on PBL implementation days and they also brought notes from their parents to excuse any absences. Mary remarked that she had the great attendance on PBL class days.

The PBL that Mary had implemented in her class was interdisciplinary in the sense that it required the students to be creative when choosing a product and company name as well as the product's advertisement. According to Mary, letting students know about the non-mathematics piece, as their product and company could be anything they wanted, excited and engaged all students, even those that shut down during mathematics class. Mary mentioned that some groups created the logo first and later brainstormed products and company name while other groups created the company and a product prior to designing the logo. During the interview, Mary acknowledged that there were discussions and arguments about products and designs but that the students resolved their own conflicts without reporting it to her for fear of losing points.

Mary designed her grading system so that individual students earned points for their contributions to the PBL case. Students also earned points as a group for the finished products and advertisements. During the interview, Mary explained that even though students realized that any off-task group members had no effect on their grades, the students still encouraged their team members to stay on task, keep noise levels down, and help efficiently manage the team. Mary gave her students a daily target, which helped the students stay on the task. In addition, during the interview, Mary bragged on the peer-evaluation component that the complete during PBL implementation, stating that the students took it seriously and evaluated their team members with fidelity. Mary discussed an incident where a student had given a team member a low score that changed to a perfect score on the last PBL class day. When asked why she had changed the score, the students replied that while that team member did not participate while the logo was initially created with functions, he played a significant role in creating the commercial. Mary realized that not every student engaged in the mathematical component of the PBL case, but they all contributed equally in the PBL case overall. Mary also noticed that the students who were usually quiet during math class took ownership of the PBL and collaborated well on the team. Mary noted the importance of seeing the “entire child” to recognize his or her strengths and also that PBL cases created an ideal opportunity for teachers to “hook” their students into mathematics by tapping into students’ interests and abilities. According to Mary, not all students have an inclination for mathematics, but teachers can always use students’ strengths to reach them.

Mary's students regularly used scientific calculators, but they had not used graphing calculators. However, during PBL implementation, the students learned how to enter and graph functions in the appropriate windows using the graphing calculator. Those students who were stronger in mathematics took the lead and taught their teammates how to use the graphing calculators. Although Mary had not planned to teach graphing of piecewise functions in a calculator, some of the students wanted her to help them incorporate such functions so that they could perfect their logo designs. Mary was happy about the dynamics of student collaboration during PBL implementation the PBL. Mary stated:

> Exciting things were occurring—people that were really not good in math realized that they had other things to offer: They might not have strong math skills, but they had strong art skills or they were strong planners or strong leaders. They were finding things about themselves. Some were artistically inclined, and some were creative, coming up with the dialogue in the commercials. Some of them were better at time management. To watch them evolve from, 'Where do I start? What is my name? I do not know what to do. What are you talking about? What is this subject?' to hearing the dialogue was rich for me. Questions were few. Questions were well thought out. It wasn't like, 'What do I do now?' It was, 'Well, I have done this. I can't get it (the calculator) to do that.' So the questions were more pointed, and the dialogue, just the dialogue itself, was rich (interview).

Cross-Case Analysis

This cross-case analysis is divided into three sections: (1) changes in participants' beliefs related to teaching and learning of mathematics (2) changes in participants' instructional practices (3) challenges in designing and implementing PBL.

Changes in Teacher Beliefs on Teaching and Learning of Mathematics

Each participant's total score regarding his or her beliefs related to mathematics teaching and learning changed by a small margin from the initial survey to the midpoint survey and from the midpoint survey to the final survey. For Jessica and George, the self-reported scores increased from initial survey to midpoint survey. However, their self-reported scores dropped on the final survey, which was completed at the end of the academic year. Jessica had 33 of 45 points on the initial survey, 36 of 45 points on the midpoint survey, and 33 of 45 points on the final survey. George had 31, 33, and 26 points, respectively. The numbers of points Mary had, which decreased on the midpoint survey and increased on the final survey, were 33, 32, and 37, respectively.

All participants agreed or strongly agreed to at least two positive statements on all 3 surveys. One of these statements was about collaboration between math and science teachers being an effective way to teach according to the Common Core Standards. Both Jessica and Mary had acknowledged on a feedback form that they had been on collaborative interdisciplinary teams in the past and that they also recognized the benefits associated with this type of collaboration, as this collaboration resulted in an interdisciplinary student activity. The other statement for which all three participants assigned the same rating was, "Solving complex problems as a group helps students to learn different ways of solving the same problem." Even though all three participants agreed that group work helps students learn multiple ways to solve a problem, my observations of and interviews with the participants somewhat showed that these three teachers rarely put students in groups in their classrooms. In addition, Jessica remarked that class size in proximity to physical classroom size was not conducive to the students working in groups.

Jessica consistently expressed her belief that students should be responsible for their own learning; Mary strongly held similar beliefs. George similarly agreed on his initial and midpoint surveys, but he remained neutral on the final survey. Jessica and Mary both consistently disagreed with the statement, "Students should not be given freedom to utilize different strategies while solving a problem," while George remained neutral at all times. Jessica and Mary wanted their students to give explanations for arriving at the solution, interested in the process as well as the end product; they did not change their stance. However, George initially agreed with the statement regarding requiring students to explain their solutions, but he later considered this unnecessary. Mary and Jessica switched from being neutral to agreeing that ill-structured problems led to deeper understanding, yet George was consistent in his belief that ill-structured problems indeed promote deeper understanding. Jessica sternly believed that students did not learn by repeating the same procedures, remarking that repetition and drills are associated with temporary memory and may not lead to sustained learning. Mary initially believed and employed repetition for concept mastery, but later realized that repetition did *not* help students learn. George initially did not believe in the effectiveness of drills, but he later shifted this belief, mentioning that drills are necessary for lower performing students to gain confidence but realizing that the problem-solving process could not be committed to memory.

All three-teacher participants were indecisive on the survey statement, "Students learn better when solving problems with a unique solution." On the final survey, all the three participants moved from an indecisive stance to agreeing with the same negative statement, thus earning only 2 points. Jessica blamed standardized tests (where there is only one correct answer) for her belief that students learn better when solving a problem with a unique solution, arguing that because the system assesses students using such problems, she should teach in the same fashion. Mary had a similar argument, declaring that standardized testing dictates the type of problems she utilizes in her classroom. Mary acknowledged that solving problems with multiple solutions helped students going on to college and throughout their careers; however, open-ended problems cannot replace problems with unique solutions in the high school classroom although both types can be used in collectively.

In the final survey, Jessica agreed with two positive survey statements and disagreed with five negative survey statements related to teaching and learning that built on PBL characteristics. In the same category, Mary agreed with three positive statements and disagreed with four negative statements. Problem-based learning is a learning philosophy built on the learning theory of constructivism. Both Jessica and Mary remained neutral to one survey statement. However, in the final survey, Mary's self–reported ratings were slightly higher than Jessica's, because Mary strongly agreed with several survey statements. George had a relatively low number of points because he disagreed with four positive statements and remained neutral to two statements. The participants' scores in the problem-solving category on each of the three surveys are presented in Figure 5.

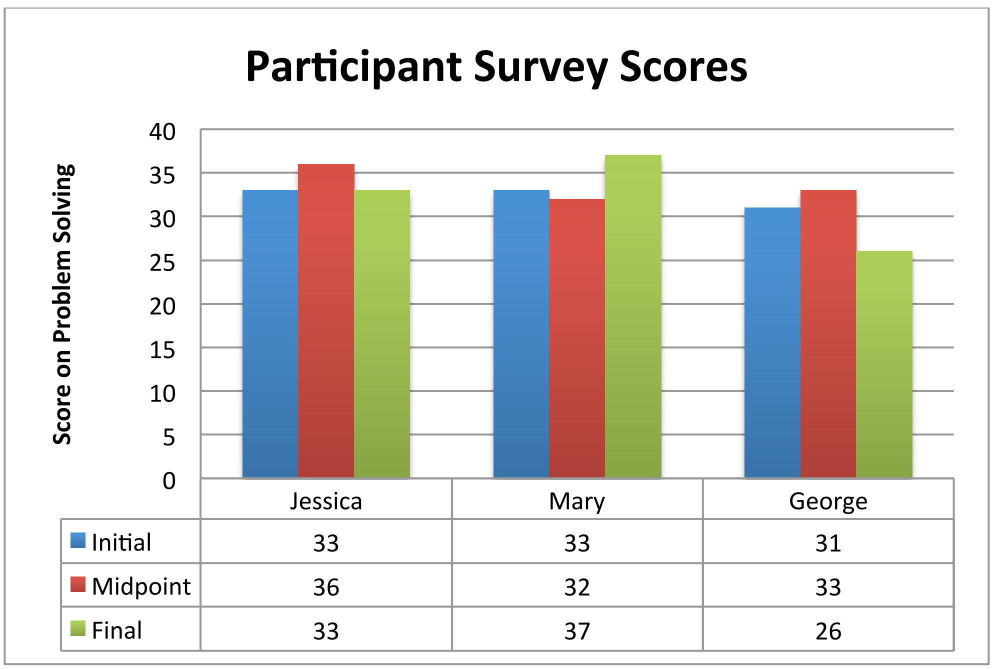

Figure 5. Participants' Scores in the Problem-Solving Category.

Changes in Instructional Practice

During the weeklong PBL academic session, Jessica and Mary collaborated with other participants to design a PBL case involving functions to implement in their integrated advanced algebra classes. However, during the academic year, both teachers had been assigned different roles and different courses to teach in the upcoming academic term. While conducting interviews, I learned that they both wanted to get comfortable with their new teaching roles before attempting to use PBL. Even though Jessica and Mary were unable to use PBL until the year's end, both participants indicated that they had been influenced by PBL in ways that changed their instructional practices. During one of my visits to HHS, both Mary and Jessica indicated that they were making conscious effort not to "give away" too much information in the classroom.

During their interviews, both Jessica and Mary discussed how they changed their instructional practices. Jessica was moving away from solely direct instruction to including inquiry-based practices, and she was also challenging students who came to tutoring. Mary said that she had started using real-world scenarios to pique her students' interests and trigger conversation among her students. Mary mentioned that she was making efforts to reduce the amount of time spent on lecture and supplement this with opportunities for student discussion. Mary mentioned that she was no longer responding to students' questions with direct answers; instead, she redirected their questions, encouraging them to think through the problems themselves to arrive at solutions. Apparently, both Jessica and Mary had made changes to their instructional practices even before implementing PBL in their classrooms.

Towards the end of the academic year, Mary and Jessica meticulously planned their PBL cases around functions in which students had to create logos (using functions) and create advertising skits; this was evident from the artifacts related to the PBL case, including all of the students' work: logos, videos of student presentations shared during PSPBL II sessions, and the interviews. Both Mary and Jessica expressed their happiness with PBL implementation and were amazed by their students' collaboration during PBL implementation. As previously stated, there is not enough information to discuss George's changes in instructional practices.

Challenges in Designing and Implementing PBL in the Mathematics Classroom

In her journal, Jessica wrote that she saw the benefit of PBL in terms of promoting critical thinking and hoped that it would help her students as well. In Jessica's second journal entry, she rated herself a 3 on a scale of 1 to 10 in terms of designing a PBL case. However, concluding the PBL academic session, she rated herself a 6 and admitted that she was comfortable designing a PBL scenario that would be interesting to her students. As Jessica reflected, her challenges were integrating the problem with the standards and creating a rubric. Mary indicated in her first journal entry that she enjoyed the PBL experience; however, she was apprehensive about using PBL in her classroom. Mary appeared certain that her students would want to quit if they had any difficulties in their thought process. In her second journal entry, she described that she was receptive to the idea of implementing PBL in her classroom and she was ready to design a PBL case to use in the upcoming fall semester along with her team of teachers. Mary expressed fears related to her students' reactions to a PBL case.

Throughout the PBL academic session, Mary discussed that she was more deeply drawn to PBL, and towards the end, she wrote that she had "grown a great deal in terms of PBL." Mary expressed in her journal that she was comfortable with the goals of PBL and with creating a PBL case from fundamental principles. According to Mary, she only needed help with the "hook" to generate students' interest. Mary stated that with practice, she would become more competent in designing PBL cases. In George's first journal entry, he noted that he recognized PBL as a technique to motivate student learning. In George's second journal entry, he indicated that he was not ready to implement PBL in his class, as he was not confident enough to design a PBL case. At the end of the PBL academic session, George acknowledged that designing PBL cases that were aligned with mathematics standards *and* tied to students' interests was a challenge.

As discussed earlier in this chapter, all teacher participants completed an initial survey, a midpoint survey, and a final survey. The third category on the survey, which consisted of 6 statements, was related to creating PBL cases was worth a total of 30 points. Mary earned the most points (27) of the three participants, followed by Jessica with 21 points on the final survey. George earned only 15 points. Mary's scores represent a high level of readiness; Jessica's scores represented an intermediary high level; and George's scores represented an intermediary low level of readiness in designing PBL cases.

The only statement that all three participants agreed or strongly agreed with on the final survey was, "Designing a PBL case pertaining to standards and appropriate for students is challenging but possible." While Jessica and George remained neutral to the statement, "Ill-structured problems can be easily designed to incorporate any mathematical and science topic," Mary strongly agreed. Again, Mary considered content knowledge essential to designing PBL cases pertaining to standards while Jessica and George did not, thus scoring fewer points.

Both Jessica and Mary agreed with the statement regarding open-ended problems in mathematics, claiming that it is easy to design real-world, open-ended problems; however, George strongly disagreed. Jessica and Mary also agreed with the statement, "Real world and open-ended problems in science can be easily designed," while George remained neutral. During the interviews, both Jessica and Mary informed me that they did not believe that their students learned well when solving open-ended problems, as they perceived that their students might get confused when dealing with problems that have multiple solutions. George felt that students learned better when dealing with problems with multiple solutions; however, he acknowledged not having provided his students with opportunities to solve open-ended problems. In agreement with their level of readiness, as evidenced by the survey scores, both Jessica and Mary designed PBL cases and implemented this in their classroom while George used a PBL designed by someone else.

Summary

The data collected from journal entries, interviews, observations, and surveys provided evidence of participants' beliefs concerning mathematics teaching and learning at various points throughout the current study. The data also provided evidence of the participants' instructional practices while designing and implementing PBL in their classrooms. According to Savery and Duffy (2001), PBL characteristics are aligned with constructivist principles. Data collected via surveys and interviews revealed that the participants' beliefs about problem solving in mathematics (mathematics teaching and learning) and beliefs about students and PBL (characteristics of PBL) are not significantly strong, which indicates that the study participants were not completely espousing constructivist principles. However, in at least two participants' cases, Jessica and Mary, there was a slight shift toward belief in PBL, hence toward constructivist principles.

Jessica and Mary initially expressed some fears but were open to learning and were enthusiastic in gaining experience in PBL and designing PBL cases during the PSPBL session. However, George strongly believed that designing PBL was a challenge for him as indicated in his journal entry; he maintained this train of thought in all of his journal entries. Jessica and

Mary were apprehensive about their students' possible reactions to PBL cases and how it would benefit them. However, Mary and Jessica showed enthusiasm throughout the course of the year and were excited about the implementation of the PBL at the end of the year. The PBL experience during the PSPBL session brought significant changes in Mary's and Jessica's instructional practices. George, however, did not show much enthusiasm about PBL despite his opinion that PBL can motivate students to take ownership of their learning.

All three study participants, Jessica, Mary, and George, initially believed that PBL was not appropriate for their student population, which according to them comprises of students having difficulties passing the standardized tests. Mary and Jessica changed their beliefs after implementing PBL in their classrooms and found that PBL cases grab the interest of those students that were once silent in mathematics classes. However, George's beliefs about his students—even after PBL implementation in his classroom—did not change.

Mary and Jessica both expressed challenges in designing PBL cases, but they felt comfortable working on a team of teachers in designing cases. Mary earned the highest number of points on the survey in the category related to designing PBL cases, which demonstrated her confidence in designing PBL cases. Jessica had the second highest number of points, and she blamed "the system" for not being able to implement more PBL cases due to the pressure of preparing students for the EOCT and increasing their test scores. George earned the lowest number of points, claiming that publishers and curriculum developers are responsible for designing PBL cases because teachers have too many other responsibilities.

Mary expressed challenges in designing PBL cases, but she felt comfortable working with a team of teachers in designing cases. Mary earned the highest number of points on the survey in the category related to designing PBL cases, which demonstrated her confidence in designing PBL cases. Her passion towards teaching and her desire to help her students achieve were motivating factors for her Mary to design and implement PBL in her classroom despite all of the challenges in terms of a new curriculum. Jessica had the second highest number of points on the survey in the category related to designing PBL cases and she blamed "the system" for not being able to implement more PBL cases due to the pressure of preparing students for the EOCT and increasing their test scores. However, as in the case of Mary, her passion towards teaching and her desire to help her students achieve helped her to overcome the challenges of not having a support team.

George, as the mathematics department chairperson had the responsibility of leading his team of mathematics teachers. He wanted to be 'in compliance' with all the reform initiatives and guidelines laid out by the school administration. George cared about his students and was interested in their overall performance and did not specifically view PBL as a way of helping students achieve. He implemented a PBL within two months of the academic session to be 'in compliance'. George earned the lowest number of points, claiming that publishers and curriculum developers are responsible for designing PBL cases because teachers had too many other responsibilities.

CHAPTER 5

CONCLUSION

In this current study, I explored the factors influencing teachers' beliefs and practices in the design and implementation of problem-based learning (PBL) in the 6-12 mathematics classrooms. The overarching research question guiding this study was, "After a prolonged engagement in professional learning on problem-based learning, what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" The overarching research question was divided into three secondary questions: (1) How are teachers' beliefs affected through a process of designing and implementing PBL cases in the classroom? (2) How are teachers' instructional practices affected through designing and implementing PBL cases in the classroom? and (3) How do teachers address challenges associated with implementing problem-based learning in the mathematics classroom?

Study participants included three mathematics teachers from the same high school who attended several PBL academic sessions over a one-year period. In this chapter, I discuss the results and conclusions drawn from the data collected through the lens of Green's analysis of beliefs. I also discuss implications for mathematics educators, administrators, and curriculum developers. Recommendations for future research are also presented in this chapter.

The Research Questions

Research Question 1

The first research question was, "How are teachers' beliefs affected through a process of designing and implementing PBL cases in the classroom?" Teacher beliefs referred to beliefs related to the teaching and learning of mathematics. Both the survey and the interview questions were focused on beliefs about teaching and learning mathematics that are characteristic of the authentic PBL classroom, which also reflected instructional practices aligned to constructivism (Savery & Duffy, 2001).

In Jessica's initial (self-reported) survey, her beliefs were supportive of constructivist instructional principles, as she agreed with seven of the nine instructional principles. However, from her interview and post-study survey it was evidenced that she did not strongly espouse the principles. Jessica "agreed" but did not "strongly agree" with any of the statements. One of Jessica's top priorities was helping her students increase their test scores on the end-of-course test (EOCT) because of the pressure associated with these scores. The EOCT requires students to answer questions with unique solutions without having to explain their reasons. This was enough of a reason for Jessica to not teach her students to solve problems with multiple solutions. Jessica also acknowledged that she was uncertain if ill-structured problems led to deeper understanding due to her lack of experience with such ill-structured problems.

Both constructivist principles and PBL require that teachers allow their students to explore the problem-solving process before fully teaching the associated concepts. Jessica's low expectations for her 9th grade students prevented her from exploring the problem-solving process; on several occasions, she stated that her 9th grade students had low mathematical ability and were immature. She felt it was her responsibility to teach her students the step-by-step procedures while they were in 9th grade. Jessica agreed that cooperative work helps students learn in different ways. However, after implementing PBL in her classroom, Jessica stated that she recognized that her students were becoming more responsible learners; they were learning from each other and also utilizing various strategies to solve the PBL problem they were assigned.

Mary’s beliefs were slightly affected because of the process of designing and implementing PBL cases in the classroom. Her self-reported survey scores changed from “intermediary agreement” to “high agreement” with constructivist principles of learning mathematics. Mary’s initial survey indicated that her beliefs were aligned with constructivist instructional principles. At the end of the study, Mary “strongly agreed” with at least five of the instructional principles. Yet, she disagreed with the principle related to providing students with opportunities to explore problems with multiple solutions; her explanation was similar to Jessica’s explanation. Mary did not want her students to work on problems with multiple solutions while the EOCT assesses students using questions with single unique solutions because the students would possibly be confused. Even though she did not identify raising EOCT scores as a priority, she constantly referred to the EOCT as if it was the main purpose of mathematics teaching and learning.

Mary initially disagreed with the constructivist principle that repetition of procedures is not necessary to learn mathematics; however, after using PBL in her classroom, she concluded that repetition is necessary only for students with low levels of mathematics achievement. Mary did not have low expectations for *all* of her students, but she divided her students into categories of low and high levels of achievement and had different expectations for students from both groups. According to Mary, constructivist methods of learning via exploration and collaboration in solving ill-structured problems are only suitable for students with high levels of mathematics achievement. During the interview, Mary noted that even her lower performing students took responsibility for their learning during PBL sessions. Implementing more PBL cases in her classroom might help Mary adhere more strongly to PBL characteristics.

George was the mathematics department chair at his school, and he felt responsible for directing PBL implementation amongst mathematics teachers at his school. George participated in the PBL activities during the weeklong PSPBL academic sessions, but he was not excited about designing his own PBL cases, unlike Jessica and Mary. George reflected very little on his journal entries, and he did not speak much in depth during the interview. His self-reported survey scores changed from "intermediary agreement" to "intermediary disagreement" with constructivist principles of learning mathematics. Although George felt that PBL could be a source of student motivation, his use of PBL in his classroom was for purposes of compliance, not interest or excitement. He only implemented a PBL that he had experienced during the PSPBL academic session and had traditional direct instructions alongside the PBL case.

George strongly believed that curriculum writers and publishers should be responsible for creating PBL cases because teachers do not have the time to invest in PBL cases. George did not implement PBL in an authentic manner; so he was unable to identify the students' reactions and responses to PBL. As it appeared, George considered PBL "one more thing/ strategy/ approach that administrators require teachers to implement" and hence had no tendency to embrace constructivists' beliefs on mathematics teaching and learning.

Overall, based on the above discussions, there was no significant change in the participants' beliefs; however, at least two study participants changed their instructional practices. Changes in instructional practices influence changes in beliefs about learning and teaching of mathematics (Raymond, 1997). Raymond proposed a model for teacher beliefs and practices in which (a) mathematics beliefs are strongly influenced by past experiences and moderately influenced by teacher education programs and teaching practices and (b) mathematics teaching practices are strongly influenced by mathematics beliefs, immediate classroom situations, moderately influenced social norms and slightly influenced by teacher education programs. Raymond's model suggests that the changes in instructional practices of the two participants might lead to changes in their belief systems after experiencing success with the instructional practices.

Research Question 2

The second research question was, "How are teachers' instructional practices affected through designing and implementing PBL cases in the classroom?" Savery and Duffy (1995) purport that PBL is modeled after constructivism for several reasons: (a) PBL enables learners to construct their own knowledge through lively engagement in authentic tasks that are vital to the environment, and (b) students must collaborate both creatively and critically to find solutions that is agreed by every member of the group. The instructional practices of both Mary and Jessica were influenced by their experiences with designing and implementing PBL cases as described below.

Mary, Jessica, and several other teachers on a grade-level team designed an authentic task requiring students to create an advertisement along with a logo for an imaginary product. While designing the task, the team of teachers considered the student population at Hopewell High School, the students' interest, and many other factors that would make the PBL implementation successful. Mary and Jessica were open to PBL and were invested in implementing the PBL case they had designed during the PSPBL academic session. However, there were external factors (e.g., changes in roles at the beginning of the academic year, the loss of team members, learning a new curriculum, pressure from an expected increase in EOCT scores) that postponed their implementation of PBL in their classrooms. Yet, this did not prevent Mary or Jessica from using certain elements of PBL in their classrooms. Both participants recognized the need to embrace new instructional strategies to motivate their students and enhance student learning.

Jessica attempted to shift from direct instructions to student-centered instructions. Jessica started allowing students to work in small groups during tutorial sessions on Saturdays to give the students an opportunity to inquire and explore mathematical concepts in more depth; she then gradually incorporated the same practices into her classroom after gaining more confidence. Jessica also started to spend less time lecturing, prompting students to ask more questions during class time. Jessica considered PBL an instructional strategy that can motivate students to take responsibility of their learning. The students' engagement, collaboration, creativity, and responsibility when working with PBL cases exceeded her expectations.

Mary started introducing her classes with the discussion of real-world problems. She also modified the way she both asked and responded to her students' questions. Mary started to allow her students to interact more during class time, provided more opportunities for students to explore mathematical concepts, and introduced other forms of assessments. Mary also started to reflect on her instructional practices with the willingness to change if it would benefit her students.

Research Question 3

The third research question was, "How do teachers address challenges associated with implementing problem-based learning in the mathematics classroom?" Each of the study participants considered their students' lack of several pre-requisite skills a major challenge in implementing PBL in their classrooms. This was reflected as 'low expectations' for all of their students. Some of the other challenges these teachers encountered when they attempted to use PBL in their classrooms, as described by the participating teachers, were increasing EOCT scores, lack of stability in terms of teaching assignments/responsibilities, constant curriculum changes, and a host of other responsibilities unrelated to teaching and learning.

During the time of the study, Mary was assigned to teach common core geometry and Jessica was teaching common core algebra and geometry; both of these courses have an end-of-course assessment. Both Mary and Jessica felt pressured to prepare their students to earn high scores on the EOCT; Jessica considered this her biggest challenge. Mary however did not state anything about EOCT explicitly. Mary and Jessica were not comfortable spending class time on PBL, as it reduces the amount of time spent on EOCT preparation. Hence, they both delayed PBL implementation until *after* the EOCT, which allowed Mary and Jessica to gradually embrace various constructivist (or PBL) practices in their classrooms. These practices included more questioning and inquiry, collaborative group work, more student interaction, fewer direct instructions, and more scaffolding. Both Mary and Jessica felt that practices such as these helped the students prepare for PBL cases.

Jessica strongly desired the support from a team of teachers when using PBL. However, the members on her team of algebra teachers did not have enough familiarity with PBL to support her. Hence, Jessica collaborated with Mary to develop a PBL case for her geometry class. Mary, on the other hand, was teaching geometry for the first time, and gained time until the end of the year to get familiarized with the curriculum before implementing PBL in her classroom. George was teaching advanced algebra, which did not have a concluding end of course test (EOCT). George's primary concerns were related to his time (and ability) to design authentic PBL cases suitable for all of his students. George expressed that retired teachers, curriculum writers, and publishers should be the ones to design PBL cases, and the PBL case he used during his class was the one from the PSPBL academic session.

Factors Influencing Teacher Beliefs

The overarching research question guiding this inquiry was, "After a prolonged engagement in a professional learning on problem-based learning, what factors influence teachers' beliefs in designing and implementing PBL as an instructional approach in the high school mathematics classroom?" The findings from this qualitative research study revealed four major themes: 1) Teacher collaboration is essential in influencing teacher beliefs in the design and implementation of PBL, 2) Pressure from the school district to increase students test scores in standardized tests prioritized learning of mathematics in the classroom, 3) Changes in terms of teaching assignment, and changes in the curriculum taught discourages teachers from embracing any innovative reform-based instructional practices like PBL in the classroom and 4) Low expectations in students' ability and performance dissuades teachers from implementing reform-based instructional practices like PBL in the classroom. I discuss each of the above themes using the data and existing literature.

Teacher Collaboration

When teachers were asked to get into pairs and design a PBL case during the PSPBL session, the 9th grade team, which included Mary and Jessica, wanted to work as a group of six algebra teachers to produce an authentic PBL case. However, during the academic year, Jessica was not enthusiastic about implementing a PBL in her classroom due to the changes that occurred at her school resulting in her being taken away from her initial team of teachers. Mary attributed her success with PBL implementation to the collaborative efforts of her geometry teaching team. A perfect example of collaborative efforts was seen on the 9th grade team during the PSPBL session, in which these teachers critiqued and revised the PBL scenario they had created. Thus, I see *collaboration* as an influential factor regarding teachers' beliefs in designing and implementing PBL in mathematics classrooms. This is aligned with the findings from the Eisenhower Professional Development Program (Garet, Porter, Desimone, Birman, & Suk Yoon, 2001). The Eisenhower Professional Development Program concluded that group participation by teachers from the same school teaching the same subject or teaching at the same grade level plays an important role in coherence and active learning, thus indirectly impacting teacher knowledge and skills and changes in instructional practices of teachers.

Prioritizing Standardized Testing

As previously stated, at least two of the study participants taught a course with a State-mandated EOCT and were responsible for helping students earn high scores on these tests, as teachers are evaluated based on their students' test scores. Serving as a deterrent to teachers trying new instructional approaches is the indirect pressure from the school districts requiring teachers to aid in students' increased test scores. Teachers are tempted to believe that high-test scores are associated with students' actually learning mathematics, which may or may not be true. All of the three study participants stated that PBL helps students gain a deeper conceptual understanding of mathematics; however, all of them considered that PBL might not effectively help students earn high scores on the EOCT. Jessica explained that PBL would not be of immediate assistance to her students, but that it might help them learn over a period of time. It was Mary's belief that PBL should be a supplemental approach and not the only approach to instruction, and she feared that PBL would have her students unprepared for the EOCT.

Several studies in which PBL curriculum is compared with traditional curriculum in terms of assessment found PBL to be effective during open-ended assessments involving the application of concepts (Walker & Leary, 2009). A meta-analysis (Gijbels, Dochy, Bossche, & Segers, 2005) conducted to explore PBL's effectiveness as compared to traditional curriculum revealed that students following PBL curriculum outperformed students following traditional curriculum in both knowledge-principle effects and the application of knowledge. In addition, Strobel and van Barneveld (2009) found that PBL is effective if assessment is based on long-term knowledge retention and if the tested knowledge requires detailed explanation. It has also been found that traditional learning methods (lecture method and direct instructions) were effective when the assessment types included multiple-choice questions, true or false statements (Strobel & van Barneveld, 2009). Since the current state standardized tests involves only multiple-choice questions, teachers are likely to believe that their practices are the best in terms of producing high test scores. Mathematics educators and researchers now have the additional responsibility of educating teachers of mathematics that learning of mathematics is more than scoring high on a multiple choice test.

Stability in Teaching Assignment and in the Curriculum

A teacher's stability in his or her teaching assignment is another factor that affected teacher beliefs related to the use of PBL in mathematics classrooms in the current study. When teachers are assigned to teach different subjects at the beginning of the year without any prior intimation, they often have feelings of distress and lose confidence when attempting to use research-based strategies in their classrooms. Generally, teachers use their first year teaching a new curriculum to get familiarized with the curriculum; they are diffident to utilize research-based strategies during this period.

Raymond (1997) opines that teacher beliefs on the nature of mathematics inhibits them from using reform based instructional practices in spite of having reform oriented beliefs on learning and teaching of mathematics. Raymond also suggests that teachers require more time than a year and support through professional development to actually start practicing reform based instructional practices. However, teachers require stability in teaching assignment or in curriculum during this time. Professional development is effective if it results in changes in teacher knowledge, teacher beliefs thus resulting in changes in instructional practice impacting student achievement. Jenkins and Agamba (2013) claim the focus on content taught and method used as one of the six key components of professional development that would make it effective. This implies that teachers are to have professional development on the content they are required to teach. Administrators have to be mindful of this fact while assigning teaching roles to teachers.

Low Expectations in Students' Ability and Performance

Another factor influencing teachers' beliefs regarding the design and implementation of PBL in the mathematics classroom is the teachers' low expectations in students' ability and performance. The study participants' first reaction to the concept of PBL was that it was a great instructional approach, but not particularly good for *their* students. The participants believed that their students lacked skills and maturity to learn through any other instructional approach other than direct instructions. It was after the teacher participants experienced PBL in the roles as student hats that they considered PBL an instructional approach to motivate their students to learn.

Several researchers (Kelly, & Carbonaro, 2012; Sorhagen, 2013) have examined the relationship between teacher expectations (stemming from beliefs about students) and student achievement. Peklaj, Kallin, Peckjak, Valenciczuljan, and Puklek (2012) identified two types of goals: mastery goals and performance goals. Mastery goals are associated with students mastering certain standards and solving cognitively demanding tasks; performance goals are associated with the display of knowledge and high-test scores. Peklaj et al. (2012) concluded that teachers' mastery goals for their students positively impacted students' self-efficacy and mathematics mastery (solving open-ended tasks). In terms of performance (actual test scores), students also responded positively to teachers' performance goals. According to Sorhagen (2013), teachers' expectations for their students as early as 1st grade have an impact on their students' academic achievement in high school. In addition, students have the tendency to believe their elementary teachers' predictions concerning their ability levels in mathematics and language; this was more pronounced in children from low-income families (Sorhagen, 2013). Expectations for students are subtle and are difficult to change because of the beliefs associated with them. Focused professional development on how to develop high expectations for all students and how to adjust teacher behavior accordingly is necessary for teachers to consistently implement PBL and other reform based strategies in the classroom.

Green's Analysis of Beliefs

Green (1971) defines teaching as an activity that facilitates in the formation of a belief system with four main characteristics: (1) a minimum number of core beliefs, (2) a minimum number of belief clusters with a maximum number of relationships between them, (3) a maximum proportion of evidential beliefs, and (4) a maximum correspondence between the quasilogical order of beliefs and the actual logical relationships between them (p. 52). According to Green's metaphor, a teacher/instructor is likely to have at least one core belief: an obsessive conviction that is based evidentially. Learning involves changes in a person's belief system that maximizes the number of evidential beliefs that also form a quasilogical system.

During the weeklong PSPBL academic sessions, teacher participants were instructed on PBL pedagogy and its power to motivate students. Mary and Jessica were inspired by the Starbucks gift card PBL case they solved during the PSPBL session. Both Mary and Jessica considered the PBL case interesting and engaging (evidential belief based on personal experience), and they thought that their students would also be engaged in their learning if they were presented with similar authentic tasks. Jessica's and Mary's journal entries indicated their beliefs in PBL as pedagogical motivation for students who are otherwise "bored" with direct instructional approaches (derived belief).

On the first day of the PSPBL academic session, both Jessica and Mary were apprehensive to implement PBL in their classrooms considering their students' ability levels. Both Jessica and Mary believed considered their freshmen students immature and void of the skills needed to learn the concepts mandated by State mathematics standards (evidential belief). This is also an evidentially held belief based on Jessica's and Mary's past experiences teaching 9th grade students and also based on their students' standardized test scores from 8th grade.

During the PSPBL academic sessions, Jessica, Mary, and other algebra teachers from their school's teaching team designed their own PBL case. This team utilized the "3C3R model" (Cs = content, context, and connection, Rs = research, reason, and reflection). Jessica and Mary had their students in mind during the planning process, and they also shared the core belief (core belief C) that all students can learn. In this study, I analyzed the process of changes in belief systems in the following manner:

C = All students can learn;

E1 = PBL is engaging and allows for critical thinking (evidential belief based on personal experience);

D1 = PBL can motivate and engage students in learning (derived belief from E1); E2 = Students lack the prerequisite skills to learn the concepts defined by the mathematics standards (evidential belief based on data and past experiences); and

D2 = PBL helps students in learning the concepts defined by the mathematics standards (derived belief from C and E2).

Problem-based learning is implemented in the classroom using an authentic task that allows students to engage in collaborative exploration. Students are motivated and engaged in the learning process and produce different results using various strategies. At this point, there is evidence that students no longer lack the skills required to learn the concepts defined by mathematics standards.

After modification, E2 becomes E3.

E3 = Students are ready to learn the concepts defined by the mathematical standards through the use of PBL (evidential belief).

Thus, there is a change in a person's belief systems, and a relationship between the primary and evidential beliefs is introduced, implying that learning has occurred. At this juncture, I would like to emphasize the fact that changes in belief systems were possible only because the participants held the core belief that "All students can learn"; it is impossible for a teacher to communicate with his or her students in the absence of this belief.

Implications for Practice

The current study has major implications for school administrators and educators, specifically high school mathematics teachers. The Common Core State Standards Initiative (CCSSI) mandates that mathematics teachers provide all of their students with the rigorous knowledge and skills they need to succeed in college and solve problems that require knowledge application and critical thinking. The eight standards of mathematics practice, as defined by CCSSI, dictate what students have to do in mathematics classrooms. Modeling with mathematics in one of the standards of mathematical practice that emphasizes on students applying their mathematical concepts to solve problems arising in real life. Teachers can do several things that may result in their students exhibiting the standards of mathematical practices:

- Provide a variety of problems in different contexts that allow students to arrive at solutions in different ways;
- Pose tasks that require students to explain, argue, or critique;
- Create opportunities for students to engage in discourse in pairs and during group instruction;
- Provide opportunities for students to solve problems in real-life contexts;
- Allow students to use structure to find patterns for themselves; and
- Allow students to seek and use their own shortcuts.

All of these teacher-led activities are possible in student-centered classrooms where the teacher uses a variety of research-based strategies. Problem-based learning is one of the instructional approaches that allow students to take ownership of their learning and follow the standards of mathematical practice.

Implications for High School Mathematics Teachers

A major finding of the current study is that in general, teachers should hold the core belief that "All students can learn." This statement implies that all students can learn according to the standards set forth by a challenging curriculum. Mathematics teachers will have to create opportunities for students to explore inquiry-based lessons and cognitively demanding tasks such as PBL cases. Modeling PBL cases with students could be a great motivator to improve students' mathematical participation in the classroom. Students that have never been exposed to challenging tasks will be discouraged initially; however, teachers must motivate their students to persevere, which can be done in many ways, such as (a) choosing a task that is relevant to the learner (should be related to his life in some way and not be something that the student has never heard or will never hear in the future); (b) choosing a task that is of interest to the learner (at least in the early stages of getting students to do tasks; (c) providing multiple pathways to complete a task; (d) providing choices in choosing tasks; (e) allowing students to collaborate; and (f) scaffolding a task by dividing it into different components. Teachers should understand that they could tap into students' knowledge reserves and increase their competence in solving challenging mathematical tasks.

Both Mary and Jessica focused heavily on preparing their students to pass the EOCT in their subject area. However, Schmidt (1983) criticized high school and college students' inability to apply their knowledge to solving real-world problems. When teachers "teach to the test," students often miss opportunities to apply their knowledge and think critically in the context of the actual problem. Teachers who use PBL in their classrooms will not only help students retain factual information, but will prepare them to be able to apply their knowledge. Self-directed learning, effective problem solving, and flexible knowledge bases are a few of the learning outcomes of using PBL (Hmelo-Silver, 2004). Teachers should view PBL as an instructional approach that supports student learning and achievement and plan to implement at least three PBL cases per semester. Collaborative team planning should give teachers the confidence to implement more PBL cases in the classroom.

Implications for Administrators

Both Mary and Jessica attributed the success of the PBL implementation in their classrooms to collaborative planning and design. Jessica postponed PBL implementation in her own classroom because she had been assigned to a teaching team different from the team she was on when the PBL case was designed. As previously stated, when teachers were in groups composed of other teachers from the same school and teaching the same subject or teaching at the same grade level for professional development activities, there was a positive influence on teachers' active learning, which indirectly impacted changes in teachers' instructional practices (Garet, Porter, Desimone, Birman, & Suk Yoon, 2001). This is true for professional development activities occurring both inside and outside of the school environment.

School administrators must establish common planning times at least once a week for all mathematics teachers to develop a professional learning committee. Common planning time is an established time during the school day during which teachers teaching the same subject/ same students meet to plan lessons using research based strategies, and conduct data analysis. According to the literature (Barrett, Riggs, & Ray, 2013) when teachers collaborate during this common planning period *during* school hours, there is measurable level of student achievement. Barrett, Riggs, & Ray, (2013) conducted a case study on teachers' collaboration during common preparation time. Their study revealed that teachers were greatly enthused to improve their lessons that resulted in student achievement.   When introducing an initiative such as PBL, common planning time becomes a necessity for teachers to collaboratively design, critique, and refine their PBL cases. This planning time also allows teachers to share teaching strategies, create common assessments, and analyze data, thus becoming highly qualified.

Administrators must also provide an ample amount of time for teachers to prepare for the courses they have to teach, as teachers are likely to be more functional when they are given their teaching assignments *before* they leave the school for summer break. Changing a teacher's assignment once school begins leaves a teacher unprepared and has an impact on student learning.

Recommendations for Further Research

In this study, I examined the factors influencing the beliefs of mathematics teachers when designing and implementing PBL in their classrooms. The collaborative nature of problem solving and the authentic real life problem in a PBL environment motivates students to be engaged in a PBL classroom. Examining student beliefs toward learning mathematics in PBL environments and examining student engagement in these classrooms would probe student perspectives of PBL, as teachers may be interested in the relationships between PBL use and student achievement as related to EOCT scores.

College and career readiness under the Common Core Mathematics emphasizes on mathematical processes and practices. Students need to be solving non-routine problems, justify conclusions, conjecture, look for patterns and predict results. PBL implementation in the mathematics classroom necessitates the standards of mathematical practices to be utilized on a regular basis. Another area of future study could be finding the correlation between PBL use in the high school mathematics classrooms and student performance in cognitively demanding tasks through the use of standards of mathematical practice. Such studies may also help boost teachers’ confidence in using PBL in their classrooms.

Research related to teachers’ behavior, classroom management, and grouping strategies during PBL implementation might be of benefit to policymakers and school administrators. PBL requires teachers to act as facilitators in the classroom guiding students by asking meaningful questions. This demands a lot of preparation time on the part of teachers. Exploring the time investment required for teachers to design and implement PBL cases and also examining actual collaboration could also be valuable areas of future study. It may also be interesting to find the alignment between teaching practices and constructivist principles for teachers using PBL cases over a period of time. The final recommendation for future study is to probe the changes in assessment methods by teachers who use PBL in their classrooms.

Summary

Reform in mathematics education is shifting away from teacher-centered instruction to more robust student-centered instruction. The process standards for mathematics designed by CCSSI (2011) and NCTM (2009) require that students acquire reasoning skills, problem-solving skills, and decision-making skills in mathematics classes, which calls for innovative teaching and instructional practices that motivate and inspire all learners, specifically those from urban areas. Problem-based learning, which is grounded in constructivism, is one of such instructional practices. The effectiveness of PBL at the university level has been addressed in the literature, specifically in medicine (Gijbels, Dochy, Bossche, & Segers, 2005; Ravitz, 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009); however, Hmelo-Silver (2004) states that limited research has been dedicated to K−12 students. In addition, PBL is not yet widely accepted as an instructional approach at the high school level because of the shortage in funding that public schools receive (Savery, 2006).

The current study contributes to the literature an examination of the factors influencing teachers' beliefs and instructional practices in the design and use of PBL in mathematics classrooms after a prolonged engagement in PBL-focused professional learning sessions. Through purposeful sampling, 3 teachers participated in the current study from an initial group of 20 teachers all from the same school; these teachers attended 2 professional development sessions during the 2011−2012 (PSPBL I) and 2012−2013 (PSPBL II) academic years on the design and implementation of PBL. The three study participants (1) completed surveys at three different time points, (2) participated in interviews, and (3) completed journal entries during a weeklong summer session. During the 2011−2012 academic year, all three participants implemented at least one PBL case in their classrooms.

All of the study participants agreed that the professional development activities were rewarding experiences that helped them become better teachers. During the summer professional development session, the three study participants worked with a team of teachers to design PBL cases that they had planned to implement in the upcoming fall semester. Only one participant was able to implement the PBL case at this time; the other two participants implemented their PBL cases at the end of the spring semester. The study participants were excited about implementing PBL in their classrooms and were quite pleased with their students' behavior during PBL implementation. The students collaborated and learned from each other, took responsibility for their learning, and were actively engaged at all times.

At least four factors affected teachers' beliefs in using PBL in their classrooms, according to the findings from this study. Teacher collaboration made teachers more confident in their ability to effectively design and implement PBL. It was also observed that teachers were at a loss when they lacked a supportive team. Teachers' low student expectations deterred them from believing that their students could solve PBL cases. Stability in teaching assignments, as assigned by school administrators, was also a factor affecting teacher beliefs about teaching and learning of mathematics. Finally, the pressure to increase EOCT scores was a factor influencing teacher beliefs about teaching and learning of mathematics. Teachers believed that PBL was a great instructional strategy to help students deeply understand concepts, but these teachers feared that problem-based learning might have their students ill-prepared for end-of-course tests. For teachers, end –of-course tests were more important than problem-based learning. However, after using problem-based learning in their classrooms, at least two teachers were inspired to use problem-based learning in their classrooms in the future. A PBL environment provides opportunities for students to embrace standards of mathematical practices as emphasized by the Common Core State Standards Initiative, the most recent significant reform in education in the United States. This study provides evidence that while teachers see the benefits of PBL in the classroom, there are barriers in the implementation phase; further professional development is needed to overcome the barriers.

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APPENDIXES

APPENDIX A

Project Success in Problem Based Learning (PSPBL)
Teacher Beliefs related to Teaching and Learning of Mathematics and Science

Code: ________________________Sex: Female / Male

Grade Level taught: 9________ 10_______ 11________ 12___________

How many years of teaching experience do you have? __________

Highest level of Education: (Circle one): Bachelor's degree / Master's degree/ Specialist degree/

Doctorate /Other: _____________________________________ (Specify)

Courses taught during 2010- 2011:

____

Please respond to the following questions by selecting one response for each statement.

PBL refers to the 'Problem Based Learning' instructional strategy in all the statements.

	Survey Statements	Strongly Agree 1	Agree 2	Neutral 3	Disagree 4	Strongly Disagree 5
1	Students understand better when solving problems with a unique solution					
2	PBL de-motivates students by not providing them enough information to solve the problem					
3	Designing PBL cases pertaining to standards and appropriate for students is challenging but possible					
4	Students go above and beyond the standards when learning through PBL					
5	PBL makes students dependent on each other for problem solving					

6	PBL does not increase test scores in mathematics and science
7	Ill structured problems can be easily designed to incorporate any mathematical and science topic
8	Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards
9	Content knowledge in the subject area is not necessary to design PBL cases pertaining to standards appropriate for students
10	PBL is an approach that motivates student learning
11	PBL enhances students' critical thinking
12	Students should not be given freedom to utilize different strategies while solving a problem
13	PBL is a fundamental shift from a focus on teaching to a focus on learning
14	Students learn to solve varied problems by repeating the same procedure again and again
15	PBL places students in the active role of problem-solvers
16	Problem solving in any topic in mathematics should be done after teaching the concept in great detail
17	Real world and open ended problems in mathematics cannot be easily designed

PBL gives students' the opportunity to
18 make decisions

When students arrive at the correct
solution, they should not be asked to
19 explain their reasoning for their solution

PBL cases based on students' interest and
related to mathematics / science standards
20 cannot be designed

Ill structured problems are more effective
21 in terms of deeper understanding

Real world and open ended problems in
22 science can be easily designed

Solving complex problems as a group helps
students to learn different ways of solving
23 the same problem

Students cannot be responsible for their
learning; they have to depend on their
24 teachers

PBL motivates students' to take
25 responsibility of their own learning

APPENDIX B

Starbucks Gift Card Giveaway

Jackson turned his laptop screen to Sam: “Hey, you should check this out on Facebook. One of my friends just sent it to me. There is a free Starbucks $25 gift card giveaway event.”

Sam: “Sweet. How does this work?”

Jackson: “If you send this advertisement to exactly 5 friends on Facebook, Starbucks will send a printable $25 Starbucks gift card in your Facebook email account.”

Sam: “I have more than 200 friends on Facebook. Guess what, I can get one for each of my family members. It will give my sister in college one week free Starbucks supply!”

Jackson: “Of course not. This is limited to only one gift card for each account.”

Sam: “Oh. Is there any other restriction?”

Jackson: “If this continues, Starbucks will stop this project once it reaches the point that they will spend $1 million a day.”

Sam: “Then just send it to me right now. It seems that this event will expire soon and I don’t want to miss it.”

Jackson: “Sorry I cannot. You see, it only works if I send it out after 24 hours someone sends to me. After that, I will have 24 hours to send it. But I promise I will send it to you when it’s the time.”

Sam: “Thanks. I am wondering how long this event will last.”

Final Product

Create a power point presentation or a poster board with the following:

a) A function in the standard form to represent the model in Starbuck advertisement situation explaining the variables used.

b) Discuss the domain and range of the function mathematically and its feasibility in this situation

c) Explain using the function and its inverse a method to calculate the number of days after which Starbucks needs to stop the advertisement

d) Explain the various possibilities in terms of the initial condition using a diagram or verbally or using a table.

APPENDIX C

Survey scores for Jessica in Problem Solving

	Problem solving	**Initial**	**Midpoint**	**Final**
1	Students understand better when solving problems with a unique solution	2	4	2
2	Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards	4	4	4
3	Students should not be given freedom to utilize different strategies while solving a problem	4	4	4
4	Students learn to solve varied problems by repeating the same procedure again and again	4	4	4
5	Problem solving in any topic in mathematics should be done after teaching the concept in great detail	4	4	4
6	When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution	4	4	4
7	Ill-structured problems are more effective in terms of deeper understanding	3	4	3
8	Solving complex problems as a group helps students to learn different ways of solving the same problem	4	4	4
9	Students cannot be responsible for their learning; they have to depend on their teachers	4	4	4
	Total (45)	**33**	**36**	**33**

APPENDIX D

Survey scores for Mary in Problem Solving

	Problem solving	Initial	Midpoint	Final
1	Students understand better when solving problems with a unique solution	1	1	2
2	Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards	4	4	5
3	Students should not be given freedom to utilize different strategies while solving a problem	4	4	5
4	Students learn to solve varied problems by repeating the same procedure again and again	2	4	4
5	Problem solving in any topic in mathematics should be done after teaching the concept in great detail	4	1	3
6	When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution	5	5	5
7	Ill-structured problems are more effective in terms of deeper understanding	3	4	4
8	Solving complex problems as a group helps students to learn different ways of solving the same problem	5	4	4
9	Students cannot be responsible for their learning; they have to depend on their teachers	5	5	5
	Total (45)	**33**	**32**	**37**

APPENDIX E

Survey scores for George in Problem Solving

	Problem solving	Initial	Midpoint	Final
1	Students understand better when solving problems with a unique solution	2	3	2
2	Collaboration of mathematics and science is an effective way of teaching and learning Common Core Georgia Performance Standards	4	4	4
3	Students should not be given freedom to utilize different strategies while solving a problem	3	3	3
4	Students learn to solve varied problems by repeating the same procedure again and again	4	4	2
5	Problem solving in any topic in mathematics should be done after teaching the concept in great detail	2	3	2
6	When students arrive at the correct solution, they should not be asked to explain their reasoning for their solution	4	4	2
7	Ill-structured problems are more effective in terms of deeper understanding	4	4	4
8	Solving complex problems as a group helps students to learn different ways of solving the same problem	4	4	4
9	Students cannot be responsible for their learning; they have to depend on their teachers	4	4	3
	Total (45)	**31**	**33**	26

APPENDIX F

Survey Scores for Jessica in Designing PBL

	Designing PBL	Initial	Midpoint	Final
1	Designing PBL cases pertaining to standards and appropriate for students is challenging but possible	3	4	4
2	Real world and open ended problems in mathematics cannot be easily designed	3	4	3
3	Real world and open ended problems in science can be easily designed	2	3	2
4	Ill-structured problems can be easily designed to incorporate any mathematical and science topic	4	3	4
5	Content knowledge in the subject area is not necessary to design PBL cases pertaining to standards appropriate for students	4	4	4
6	PBL cases based on students' interest and related to mathematics / science standards cannot be designed	3	4	4
	Total	**19**	**22**	**21**

APPENDIX G

Survey Scores for Mary in Designing PBL

	Designing PBL	Initial	Midpoint	Final
1	Designing PBL cases pertaining to standards and appropriate for students is challenging but possible	4	5	4
2	Real world and open ended problems in mathematics cannot be easily designed	3	4	5
3	Real world and open ended problems in science can be easily designed	3	4	4
4	Ill-structured problems can be easily designed to incorporate any mathematical and science topic	4	4	5
5	Content knowledge in the subject area is not necessary to design PBL cases pertaining to standards appropriate for students	3	4	5
6	PBL cases based on students' interest and related to mathematics / science standards cannot be designed	4	2	4
	Total	**21**	**23**	**27**

APPENDEIX H

Survey Scores for George in Designing PBL

	Designing PBL	Initial	Midpoint	Final
1	Designing PBL cases pertaining to standards and appropriate for students is challenging but possible	3	4	4
2	Real world and open ended problems in mathematics cannot be easily designed	4	4	3
3	Real world and open ended problems in science can be easily designed	2	4	2
4	Ill-structured problems can be easily designed to incorporate any mathematical and science topic	4	2	1
5	Content knowledge in the subject area is not necessary to design PBL cases pertaining to standards appropriate for students	3	4	2
6	PBL cases based on students' interest and related to mathematics / science standards cannot be designed	3	3	3
	Total	**19**	**21**	**15**

APPENDIX I

Daily Activities for PBL Designed by Mary and her team

Date	Activities
5/7/12	1. Introduce the PBL (What is it? Purpose?) 2. Assign Groups 3. Have students assign roles 4. Collectively establish Group Rules (Recorder writes on paper)
5/8/12	1. Students read scenario and discuss 2. Students complete Box Chart 3. Begin working on solution
5/9/12	1. Continue working on solution
5/10/12	1. Finalize all work including sketch of diagram 2. Make sure all questions are answered
5/11/12	1. Work on presentations 2. Create poster for visual aid 3. Assign roles for presentation
5/14/12	1. Continue to work on presentation 2. Poster should be colorful 3. Teacher tallies class work
5/15/12	1. Finalize presentation 2. Practice speaking parts (all students should speak) 3. Students complete Peer Evaluation 4. Teacher finalizes tally for class work (out of 150)
5/16/12 – 5/18/12	1. Final Exam is presentations 2. Rubric should be completed during presentation 3. Grades will be completed at end of session