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**PROBLEM-BASED LEARNING:
MATH MADE RELEVANT**

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ABSTRACT

This action research study documents the observed behaviors and reported experiences of 11th and 12th grade Algebra II students when implementing problem-based learning (PBL). This study found that approaching Algebra through real word examples and PBL afforded students the chance to develop in-depth understanding of mathematics concepts such as linear equations and their graphs as well as developing 21st century skills such as communication and organization. This study also suggests that teacher intervention during group work time is a critical step in implementing PBL effectively.

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TABLE OF CONTENTS

ABSTRACT	iii
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	viii
LIST OF FIGURES	ix
RESEARCHER STANCE	1
LITERATURE REVIEW.....	4
Traditional Setting.....	4
What is PBL?	5
PBL Classroom Structure.....	8
Question	8
Student Grouping	9
Work Time.....	10
Class Discussion	12
Final Presentation.....	13
Outcomes	14
Student Perception	17

Conclusion	20
RESEARCH DESIGN AND METHODOLOGY	22
Setting and Participants.....	22
Trustworthiness Statement.....	22
Data Sources	23
Surveys (Pre- and Post-)	23
Field Journal and Reflective Online Journal.....	24
Student Artifacts.....	24
Mid-Study Questionnaire.....	25
MY STORY	26
DATA ANALYSIS	51
Data Sources	51
Bins and Theme Statements.....	56
RESEARCH FINDINGS.....	59
Cognitive Skills.....	59
Student Interaction.....	62
Other Skills	66

Teacher Intervention.....	69
Difficulties	71
THE NEXT STEP.....	74
REFERENCES	77
APPENDICES	81
A. Human Subjects Internal Review Board Approval	81
B. Principal Consent Form.....	82
C. Parental Consent Form	83
D. Pre- and Post-Survey	84
E. Mid-Study Questionnaire.....	85
F. Problem-Based Learning Evaluation Rubric.....	86
G. Self-Assessment for Group Work.....	87

LIST OF TABLES

Table 1. Pre- and Post-Survey Summary

Table 2. Evaluation Rubric Summary

LIST OF FIGURES

Figure 1. Slide one: “Help me Prevent Disaster.”

Figure 2. Slide two: “Help avoid this!”

Figure 3. Slide three: “All you need to know.”

Figure 4. Area of Shower Wall

Figure 5. List of Tools and Materials

Figure 6. Slide: “Who pays for the show?”

Figure 7. Drama- Charlene’s Project

Figure 8. Solving Systems of Equation using Substitution

Figure 9. Solving Systems of Equations by Graphing

Figure 10. Pastiche- Four Students’ Voices

Figure 11. Bins Showing Related Codes

RESEARCHER STANCE

I can recall sitting in math class in 4th grade, listening to my teacher day in and day out explain fractions, estimation, and word problems. Math came easy for me except for the word problems. In spite of my fear of word problems, it was then in Mrs. Gozzard's class that I first thought, "I want to be a teacher." All through school, math was my favorite subject. I connected with my teachers, and they made math fun. Once enrolled in a secondary education program in college, I knew the reason I was there was because I had inspiring math teachers growing up and I wanted to give to my own students what they had given to me.

Throughout my six years of classroom teaching, I have tried to create an environment where students don't hate math. I try to teach the importance of math, while making learning enjoyable. In my experience as a teacher, I have found that word problems tend to be my students' worst math nightmare. At some point, students must overcome their fear of word problems because life does not supply math problems out of context. I eventually overcame my own fear as a student, and now I try to help my students do the same. Problem-based learning offers them the opportunity to begin to do so.

Problem-based learning allows students to investigate a problem relative to their lives and also allows students to investigate and find solutions in a natural way. While students work through the problem, they may require new math skills,

which is where I come in. Through this problem solving process, I hope to have my students learn imperative collaboration and problem solving skills as they meet mandated state math standards.

Problem-based learning does not come naturally to most of my students. By the time they get to my high school classroom, they have learned over many years of traditional public schooling to seek out the right answer. I find that students often simply play school to get a grade. Many memorize information for a test and then forget it as soon as the test is over. Problem-based learning allows students to discover and create a solution with the guidance of a teacher.

The catch to problem-based learning is that students need to learn to be motivated. To be successful in life, not just school, students need to have a strong work ethic and enjoy learning new things. With problem-based learning the teacher's role is to facilitate and guide learning, not force feed content knowledge.

Not all students, of course, have the same educational beliefs that I do. I tell my students that I believe in a strong work ethic, which includes completing work on time, not wasting the time of others, and having a good attitude with regards to school work. I also believe in practice, for without practice we cannot expect to get better at a new skill. And I believe in learning to learn. I describe learning to learn as finding the enjoyment in learning just because it's fun. Based on my values, I have come to teach the way I do. On a daily basis I try to infuse

my classroom with these values. Problem-based learning is one technique I believe fosters the growth of the educational values I hold.

These experiences and beliefs have led me to ask the following questions: What are the observed behaviors and reported experiences of high school Algebra II students when implementing problem-based learning? What are the effects of problem-based learning on students' ability to think for themselves? What are the effects of problem-based learning on students' understanding math's purpose in everyday life? And what are the effects of problem-based learning on students' written communication skills?

LITERATURE REVIEW

Traditional Setting

In Thomas and Monroe's "Self-Study of a Teacher's Journey toward Standards-Based Mathematics Teaching," Thomas described himself as a "dispenser-of-knowledge" where he presented mathematics at an "incomprehensibly fast rate" (p. 170). His students sat in organized rows, faced front, and were expected to complete their work quietly. Thomas expected students to use paper, pencil, and the textbook as their major tools (2006). Traditional teaching thrives on the students' ability to memorize existing rules and theorems and then apply the rules to find the one and only answer (Kwon et al., 2006). In a traditional setting, the textbook is the primary instructional resource which guides the introduction of new concepts and provides a regular assessment (Ridlon, 2009).

Freire (1970) describes teacher centered narration as an environment that encourages students to memorize or bank the narrated content. Narration turns students into "containers" which will be "filled" by the teacher. The more the teacher fills the containers the better the teacher, the more the containers allow themselves to be filled the better the student. Freire (1970) refers to this traditional type of teaching as banking education. Banking education suppresses and stifles creativity, problem-solving education enables constant disclosure of

reality. In the traditional model, students only receive instruction on mathematical concepts.

According to Partnership for 21st Century Skills (2002), to be successful one must think critically, apply knowledge to new situations, analyze information, comprehend new ideas, communicate, collaborate, solve problems, and make decisions. In the 21st century, people need these skills not only to be successful in their professional lives, but also to make intelligent consumer choices and to raise children. The Partnership for 21st Century Skills (2002) suggests providing students with authentic learning experiences that make content relevant, bring the world into the classroom, create opportunities for working in groups, and create opportunities for working with teachers or experts in a specific field. One method of bringing these ideas into a classroom without excluding mathematics core content is problem-based learning (PBL). Through my review of the literature, I will define PBL, describe the best practices in PBL discourse, and examine student achievement outcomes and student perceptions in PBL environments.

What is PBL?

PBL is quite simply a problem solving approach in which students solve problems or find solutions for “mathematical situations for which no-well defined routines or procedures exist” (Erickson, 1999, p. 516). These situations cannot be solved by well defined routines because PBL is based in real world situations. In

real life, problems are not solved with one correct procedure as they so often are in a textbook. However, according to National Council of Teachers of Mathematics (NCTM) the teacher should identify a specific mathematics concept to focus students' attention throughout the problem solving task (as cited in Erickson, 1999). By choosing the task or problem, the teacher addresses required mathematics standards while allowing students to develop their own problem solving methods.

Problem-based learning is a method of teaching that presents school mathematics in the context of real world problems that students might encounter (Flores, 2006). Since these problems are real and familiar to students, PBL can be motivational (Flores, 2006). The real world context gives mathematical concepts purpose and meaning (Clarke & Roche, 2009). When students solve problems through problem-based learning methods the question "Why do we need to know this?" is answered before it can be asked because the question is from a familiar real world context.

Researchers and source authors refer to the same or similar practice of problem-based learning by many different names, including problem-solving tasks (NCTM as cited in Erickson, 1999), contextual learning approach (Sounders and Prescott, 1999), open-ended approach (Kwon, Park, and Park, 2006), "Type 2 Task" (Clarke and Roche, 2009), and problem-centered learning (PCL) (Ridlon,

2009; Wheatley, 1992). These terms all define a practice in which the problem sparks the students' interest by being relevant to their lives and allowing them to find their own path toward a solution. The NCTM uses the term "problem-solving tasks" to identify situations in which the method of solution cannot be determined by an easily accessible procedure or algebraic algorithm (as cited in Erickson, 1999). Contextual learning approach is the term used by Sounders and Prescott (1999), who define their practice as making learning meaningful and relevant with problems that favor a wide variety of learning styles. The open-ended approach used by Kwon, Park, and Park (2006) is a "pedagogical strategy that aims to produce creative mathematics activities that stimulate the students' curiosity and cooperation in the course of tackling problems" (p. 52). Clarke and Roche (2009) identify a Type 2 Task as a "contextualised practical problem where the motive is explicitly mathematics" (p. 25). The Interactive Mathematics Project (IMP) sets three major goals: problem solving, reasoning, and communication. To meet these goals the instruction focuses on mathematical concepts and skills in a context that provides a rationale for the skills and a means of integrating new knowledge (Clarke, Breed, & Fraser, 2004). Ridlon (2009) and Wheatley (1992) both use the term problem-centered learning (PCL). Ridlon (2009) notes that in PCL, meaningful tasks are provided to the class and then solved in collaborative

groups. I have chosen to use the term problem-based learning because I feel the name best describes the student learning that occurs in the context of solving real world problems.

PBL seeks to accomplish many more goals than acquiring core mathematics concepts. Problem-based learning aims at teaching and nurturing many learning skills, including communication, problem-solving, and interpersonal skills (Partnership for 21st Century Skills, 2002). When students are provided opportunities to solve open ended problems in a group, they are placed within an environment that encourages critical thinking, self-directed learning, and understanding through teamwork (Azer, 2009). Murray-Harvey, Curtis, Cattley, & Slee (2005) note that PBL focuses on: “problem-solving, communication skills, and interpersonal skills” (p. 259). PBL also promotes the development of higher-order thinking and students social skills (Azer, 2009). Problem-based learning tasks require students to perform in many ways by organizing, researching, problem solving, and synthesizing (Sounders & Prescott, 1999).

PBL Classroom Structure

Question.

Every math problem starts with a question that serves as the driving force of problem-based learning. Typically, the teacher will pose the question, but in

PBL a student could just as easily pose the question as well (Ridlon, 2009).

Unlike a textbook question, the PBL question is grounded contextually in real life. Dewey (1938) suggests that what is taught in school must connect directly to the real life experiences students have and will have in the future. Students will not find this way of learning boring due to the relatability to their lives. Putting the problem in a real-life context helps students realize why the problem needs to be solved in the first place. The context should be familiar to all students and should encompass an interesting topic (Kwon et al., 2006). It must be “suitable for mathematical thinking and should also spark new problems that the students want to answer” (Kwon et al., 2006, p. 52). Erickson (1999) suggests the problem lend itself to “using multiple solution strategies, multiple representations of the concept, and mathematical communication that includes explanation and justification” (p. 517). Pearlman (2006) insists problems be designed to meet state content standards and 21st century skills, including collaboration, critical thinking, written communication, and oral communication.

Student grouping.

Once the problem has been posed, students should be assigned to groups. When the teacher builds an experience, he or she needs to consider a student’s physical and social surroundings. Educators must structure an experience so students want to solve the problem to their fullest ability as to make the

experiences educative and not miseducative (Dewey, 1938). Ridlon (2009) suggests groups of “two or three students of similar capabilities” (p. 195). Wheatley (1992) agrees with Ridlon, stating that students should be placed in groups based on mathematical development. Each problem should allow for “various solutions at diverse levels,” and grouping students together with like achievement levels will give students a sense of “achievement and fulfillment” because students find solutions within their own range of current academic performance; this allows all students to contribute and to achieve at the highest level possible (Kwon et al., 2006, p. 53).

Work time.

After groups are assigned, students begin to work on the problem. This initial investigation period generally lasts only about 20 to 30 minutes (Wood & Sellers, 1996; Ridlon, 2009). During this initial time, groups brainstorm methods to solve the problem. Students do preliminary research and explore many possible solution methods. Once this initial brainstorming session has ended, a whole class discussion will occur, which I’ll address in more detail in the next section. Then, group work will continue for multiple class periods, depending on the difficulty of the problem.

Students should work towards developing their own solution methods (Wood & Sellers, 1996) while the teacher provides students with manipulatives,

calculators, or other tools they may need to use during this group work period (Trafton & Hartman, 1997; Thomas & Monroe, 2006; Ridlon, 2009). Students should also be provided with research tools, such as internet access (Flores, 2006; Pearlman 2006). Furthermore, the National Council of Teachers of Mathematics (2000) strongly supports student use of various electronic technologies such as computers, calculators, and specialized software.

Pearlman (2006) notes that throughout group work time, students learn to collaborate and work as a team, think critically, communicate, and use technology. He says a computer with internet access allows students to “research any topic, communicate with experts and teachers, write journals and reports, and develop presentations” (p. 5). Group work in a PBL classroom serves as more than a time to find the answer, permitting students to work as part of a team, to conduct research and explore the problem, and to develop patience and persistence, all while expanding their problem solving skills and mathematical knowledge.

Throughout the work periods, the teacher takes on an important role. In contrast to a traditional classroom where the teacher is “the expert, they are now a resource” (Flores, 2006, p. 161). Flores (2006) describes the teacher as a coach who helps students think metacognitively and guides them as they search for a solution. One way a teacher can guide students is by asking clarifying questions, including, “What do you know? How did you solve similar problems? Would it

help to draw a picture, make a diagram, or use other tools?” (Nugent, 2006, p. 287). Dan Meyer (2010) encourages teachers to “be less helpful” in his TED (Technology Entertainment and Design) talk, “Math Curriculum Makeover.” Meyer wants his students to think for themselves without being inundated by pre-planned formulas, methods, and solutions. The teacher’s purpose is to facilitate, question, and guide learning, not be the sole knowledge holder and provider (Flores, 2006; Nugent, 2006).

Class discussion.

Once students have had sufficient time to work toward exploratory solution methods, the whole class comes together for a discussion. During this discussion, the teacher acts as a facilitator, while selected groups present their preliminary ideas and solutions. The groups selected by the teacher may not all have the correct solution, but these groups have important insights to offer the class as a whole (Ridlon, 2009). Malouff and Schutte (2008) agree that students can learn “from both failures and successes” (p. 7) if teachers keep the learning process of problem solving as the focus.

While groups are presenting their preliminary ideas, Ridlon (2009) suggests the class act as a “community of validators,” (p. 195) who determine the effectiveness of the solution methods and the teacher remains nonjudgmental. The class may request clarification of solution methods at this time (Wheatley, 1992).

Clarke and Roche (2009) and Trafton and Hartman (1997) agree that during the clarification process, the teacher should highlight the main mathematical concepts of the lesson so all students understand them. It is a teacher's responsibility to not force learning but to facilitate, guide, and interpret the group's suggestions (Dewey, 1938). After the group discussion, students are given an extended period of time to solve the problem using their own methods (Kwon et al., 2006; Wood & Sellers, 1996) and to make adjustments to their original methods. The prime purpose of the group discussion is for the class to learn from each other's thought process and to promote self- efficacy (Cerezo, 2004).

Final presentation.

The last phase of PBL is final presentation day. By including a presentation, the teacher provides an audience. Sounders and Prescott (1999) note that, "When students gain a public audience, the significance of their work grows in importance and they take it far more seriously" (p. 42). Lovitt (1999) refers to the presentation step as "publish or perish," (p. 5) implying publishing, or presenting, is critical to the PBL process. Solutions and findings could be presented through writing an explanation, giving a presentation (Erickson, 1999), presenting a PowerPoint (Flores, 2006), or creating a web page (Sounders & Prescott, 1999). Pearlman (2006) recommends that groups present their findings and solutions to an outside panel of experts. These experts may be parents,

community members, or professionals in their field (Pearlman, 2006). There are many methods of presentation that are acceptable, but all cases require explanations (Cerezo, 2004).

Nugent (2006) suggests that an oral presentation may not always be the most effective way to communicate a group's findings. Writing a letter to a stakeholder, for example, could prove to be a more meaningful way to share students' findings. Nugent explains that the first step in writing might be a teacher-initiated brainstorming session to identify the process students went through to solve the problem. Then she recommends matching the steps of the process with the reasons why those steps were completed. In a traditional class, at the end of a chapter students are expected to take a test to show their knowledge. In a problem-based learning class, students are more likely to give a presentation that is assessed using a rubric (Flores, 2006). The presentation not only reveals content knowledge but also allows students to communicate about mathematics to the people the problem and solution affect most.

Outcomes

In recent years No Child Left Behind (NCLB) has kept many schools focused on high-stakes testing. Due to high-stakes testing pressure, important problem solving skills have all too often been left to the wayside and replaced with test preparation (Higgins, Miller, & Wegmann, 2006). In three California

high schools, Clarke, Breed, and Fraser (2004) set out to investigate if student achievement on conventional mathematics tasks could be enhanced and if a problem-based program could increase student performance on non-routine problem-solving tasks. Over three years, an Interactive Mathematics Project (IMP) was implemented. IMP uses a problem-based approach that targets specific mathematical concepts and skills in a context that provides a reason for the skills. The goals of IMP were to broaden who learned mathematics, expand what math was learned, change mathematics instruction, change how teachers perceived their roles, and change how mathematics learning was assessed.

The IMP classrooms averaged 32 students. Activities included group work, writing, oral presentations, and graphing calculators were available at all times. Grades in the IMP classroom were tabulated from student performance on homework, class work and participation, problem of the week, and unit assessments. Control data were collected from Algebra classes at the same level as the IMP students. To examine student perceptions and beliefs, two surveys were administered, and the information collected from the surveys was then validated through student interviews. In addition to surveys and interviews, The Mathematics Scholastic Aptitude Test (SAT) was administered to allow for comparison of mathematical performance of IMP students and traditional students.

At the conclusion of the study, Clarke et al. generalized their findings into five areas: student perceptions of their mathematics competence, student attitude toward mathematics classes, student perceptions of mathematical activity, student perceptions of mathematical ideas, and student mathematics achievement on conventional tests. Clarke et al. (2004) concluded that IMP students were significantly more likely to rate themselves high on how good they were at math and to feel positive about mathematics classes. IMP students perceived mathematics to be a mental activity more than traditional students. IMP students were more likely to view mathematics to have developed from people's actual needs. Finally, in comparison with traditional students at the same school as the experimental IMP students, mean SAT score for IMP classes were reported as being higher than mean SAT scores for traditional Algebra classes. Problem-centered approaches provide students the opportunity to enhance communication and thinking skills, while improving overall achievement and standardized test scores (Ridlon, 2009). In addition to communication and thinking skills, Murray-Harvey et al. (2005) offer that involvement in researching authentic problems allows teamwork and problem-solving skills to be developed, while also learning core subject matter. Wood and Sellers (1996) found that even elementary students in problem-centered classes scored significantly higher on standardized achievement tests than did students in non-problem-centered classes.

Student Perception

Some of the most important outcomes of instruction are not what can be measured by a test, but what students think about themselves, others, and their ability to succeed. Wood and Sellers (1996) found that both second and third graders reported that they would rather not copy the teacher and believed finding their own methods and different ways to solve the problem was important. Trafton and Hartman (1997) agree that students who learn in a problem-based setting become mathematics investigators who are confident and capable problem solvers.

Cerezo (2004) surveyed and interviewed middle school students regarding their beliefs and perceptions of a PBL environment. Students reported that they enjoyed being challenged to think differently, were open to new ideas, were non-judgmental, and were supportive of each other. Students also acknowledged their need and want to socialize while learning, meaning that successful collaboration contributed to their perceived success at finding a solution. Finally, students in Cerezo's study perceived increases in their own confidence, involvement, and interest with a deeper understanding of mathematics concepts in a PBL environment.

Furthermore, Ridlon (2009) investigated the effects of the Problem-Centered Learning (PCL) approach on students' beliefs, feelings, and opinions

towards learning mathematics. This study took place in a class of sixth-grade low achievers and in a classroom with children of mixed achievement over two years in nine week periods in a rural southern middle school. The experimental treatment group was a sixth grade class that received instruction through a problem-centered approach, and the control group was a comparable sixth grade class that received instruction through the traditional explain-practice approach. The mathematics content studied in both groups was identical, originating from the same district sanctioned textbook.

In the PCL classroom, the teacher or a student would pose a problem. Then, the class was organized into groups and began to collaborate on the task. During this time, students received unrestricted access to manipulatives and calculators. As students worked on their problem, the teacher circulated from group to group, listening, asking questions and selecting groups for future presentations. After one or more periods of work time, a whole class discussion and presentations would ensue, providing students with the opportunity to ask questions and to justify, clarify and then amend their work. In the traditional classroom, students were introduced to new concepts and assessed weekly. Classroom discourse was primarily teacher-centered; manipulatives were rarely used; and calculators were only used with teacher permission.

Ridlon administered pretests and posttests to both classes with questions modeled on the mathematics section of the Iowa Test of Basic Skills and gathered additional data through the use of student and parent surveys, interviews, and observations. Once a week students also responded to open-ended questions in a reflective journal where they stated their beliefs, feelings, opinions, or showed their mathematical understanding.

Student and parent survey responses showed a pattern of believing that PCL increased grades and achievement in the experimental group. Also, parents reported that their students understood math better. Furthermore, interviews with students and parents validate the survey results in regards to perceived achievement. Three students who were interviewed said that “math made more sense” in the problem-centered learning class and they “had better grades” (p. 215). A parent who was interviewed commented that their PCL child’s “achievement is better this year than last year” (p. 215).

Observational notes suggest that students’ attitude toward mathematics and participation during group discussion improved. An outside observer reported that students were “excited” about mathematics and “eager to explain” (p. 215). One student in the PCL class explained, “Math was my worst subject. But now I feel math is fun and you can learn a lot of stuff. I enjoy math this year and write in

my journal everyday. I feel kind of excited and happy. I enjoy this class more than others but band. It's just great in this class" (p. 216).

Conclusion

Problem-based learning is a problem solving method in which students solve true life problems, where no set procedures can be applied, through teamwork, communication, research, and their own problem solving methods (Azer, 2009; Clarke et al., 2004; Clarke & Roche, 2009; Dewey, 1938; Erickson, 1999; Kwon et al., 2006; Murray-Harvey et al., 2005; NCTM, 1989; Ridlon, 2009; Sounders & Prescott, 1999; Wheatley, 1992). The goal of PBL is not only to teach math content standards but to provide students an environment that encourages independent thinking, teamwork, self-efficacy, problem-solving skills, communication, creative thinking, and work ethic (Azer, 2009; Cerezo, 2004; Clarke et al., 2004; Freire, 1970; Kwon et al., 2006; Murray-Harvey et al., 2005; Partnership for 21st Century Skills, 2002; Ridlon, 2009; Sounders & Prescott, 1999; Wheatley, 1992). Many sources suggest a PBL classroom include a teacher posed question, homogenous groups of two or three students, initial investigation period of approximately 30 minutes, whole class discussion about initial theories and solution methods, final work time to find solutions and prepare presentations, and conclusion of a presentation to the class, panel of experts, or other problem

related stake holders (Cerezo, 2004; Clarke & Roche, 2009; Dewey, 1938; Erickson, 1999; Flores, 2006; Kwon et al., 2006; Lovitt, 1999; Malouff & Schutte, 2008; Nugent, 2006; Pearlman, 2006; Ridlon, 2009; Sounders & Prescott, 1999; Trafton & Hartman, 1997; Wheatley, 1992; Wood & Sellers, 1996). Implementing PBL in the classroom includes a wide range of outcomes. Researchers have found that PBL encourages communication skills, thinking skills, teamwork, problem-solving skills, confidence, involvement, deep understanding of content, and interest amongst students (Cerezo, 2004; Dewey, 1938; Freire, 1970; Murray-Harvey et al., 2005; Ridlon, 2009). In addition to acquiring a vast range of soft skills, researchers have found that problem-based learning improves students' understanding of core subject content, overall achievement, and standardized test scores (Cerezo, 2004; Clarke et al., 2004; Murray-Harvey et al., 2005; Ridlon, 2009; Wood & Sellers, 1996).

RESEARCH DESIGN AND METHODOLOGY

Setting and Participants

I teach 11th and 12th grade Algebra II College Preparatory in a performing arts charter high school with approximately 450 students, grades nine through 12 located in eastern Pennsylvania. This charter school has a very diverse population pulling from 49 school districts. These school districts range from urban to rural communities. The school is made up of 73% Caucasian, 10% Hispanic, 6% African American Non-Hispanic, and 11% other races.

In my Algebra II CP class, there are 11 juniors and two seniors, four are boys and nine are girls. One of my students is repeating Algebra II and 12 are taking the class for the first time. This Algebra II class, as well as all academic classes in the school, meets every other day for 55 minutes. The class is held during the last period of the day.

Trustworthiness Statement

Approval for this study has been granted by the Human Subjects Internal Review Board (HSIRB) of Moravian College, Bethlehem, PA (Appendix A). I have also been given written consent to conduct this research study by my principal (Appendix B). I have acquired signed parental consent forms for all students participating in the study (Appendix C). Participation in this study was

completely voluntary and opting out of the study did not carry any consequences for the student.

In order to keep my participants safe, their names were kept confidential along with the name of the school where research was conducted. Only my name, the names of my sponsoring professors, and Moravian College appear in the study. All students participating in the study were assigned pseudonyms and no names appear on any artifacts or reports. All research materials and data collected were kept in a secure location for the duration of the study and at its conclusion were destroyed.

According to MacLean and Mohr (1999), “Validity in research is the degree to which a study is honest and true to its intent, its context, and its reporting. It is the result of your integrity both as a teacher and as a researcher” (p. 117). To ensure validity in my study I used triangulation of multiple data sources: Surveys, Field Journal and Reflective Online Journal (Blog), Student Artifacts, and Questionnaires.

Data Sources

Surveys (Pre- and Post-). Before my students began working on their first Problem-Based Learning task, they completed a pre-survey (Appendix D). This survey allowed me to assess my students’ opinions of the usefulness of math

to them so far in their life. It also gave me access to their opinions on their own math understanding and learning styles.

After completion of each PBL task, students completed the same survey. This cycle continued a total of three times. After the third post-survey had been completed an analysis of the survey results occurred.

Field Journal and Reflective Online Journal (blog). Throughout PBL class work time I took observational notes and recorded student quotes in a field journal. During this time I did not make judgements, assumptions, or interpretations of what I saw happening in my classroom. I wrote down what I saw and what I heard. Shortly after class ended I re-read my observational notes and quotes and typed a reflective blog entry. In each blog entry, I recapped and analyzed the events of the class period. Throughout my blog entries I also included posts on individual students who were making an notable impact on my research study.

Student Artifacts. During the research period, students created group wikis, presentations, self-assessments for group work, and evaluation rubric. The wikis allowed me to assess students' understanding of each PBL task on a day to day basis. I provided ongoing feedback for each group before it was time for their presentations. The presentations allowed students to explain their process and understanding of their solutions in their own words. It also allowed students to use

creativity and technology to help them in their explanation of how math related to their everyday life. The self-assessments gave students an opportunity to express their difficulties or accomplishments either personally or within their group and allowed students to express individual concerns with their group members. Finally, the evaluation rubric allowed me a preset standard for my students to work toward and allowed me to assess each group fairly and equally based on those standards.

Mid-Study Questionnaire. After the second PBL task I administered a mid-study questionnaire (Appendix E). These questions asked students to describe what they found difficult during PBL class work time and presentations and how they could improve their solutions. These questions helped me to decipher the students true feelings toward PBL. Did they enjoy learning through this instructional method or do they just view it as time they are not listening to me?

MY STORY

I was first introduced to Problem-based learning (PBL) during “Digital Alternatives to Test Preparation” in the spring semester of 2010 at Moravian College. During this class I was introduced to various instructional methods that encouraged developing 21st Century Skills in students while meeting state testing requirements. Of the instructional methods discussed, I choose to investigate PBL more.

Fall 2010, after my brief study of Problem-based learning practices, I attempted to implement PBL in my classroom. I came up with three problems. At the time I thought I was well prepared. I planned on group discussions and work time. But when the classes started and students started to research the problems I quickly got sucked into explaining directions and theory to each group. This quickly frustrated me, left my students confused and discouraged, and caused me to not assign the third PBL that I had prepared. It was still winter when I gave up on PBL for the 2010-2011 school year.

When it was spring semester again, 2011, I was still completely enamored with PBL. I hoped that with a structured lesson plan and more research, PBL would be successful. I had my research question, "What are the observed behaviors and reported experiences of high school Algebra II students when implementing Problem-based learning?"

Throughout the spring semester and while writing the literature review I realized I was going to have to devote my entire summer to creating the lesson plans for my PBLs and still take one more elective. Dr. Shosh recommended an independent study where I would do a little more reading on my topic while creating complete lesson plans that would be ready to implement in my classroom the following fall. What a perfect idea. At this point all I knew was that I wanted the PBL to apply to my students lives and use technology.

After a summer filled with PBL research and problem creation the thought of implementing PBL in my classroom for a second year looked promising. The previous year, 2010-2011, I tried implementing PBL hastily on a whim of inspiration from my class, “Digital Alternatives to Test Preparation”. My tasks were not fully developed, my lesson plans were vague, and each tasks concluded with an analytical explanation of how my students arrived at their solution. After the third PBL task and too many student groans to bear I gave up on PBL for that year.

Still inspired by the concept of PBL and after extensive research for my literature review, I engaged in an independent study to turn what I read were best practices in PBL into detailed lesson plans to be implemented the following fall, 2011. During my independent study, I challenged myself to design problems that were introduced with an intriguing video, engaging for my students, and that

needed technology for more than just researching the web. With these goals set, but with questions on how else to include technology my professor suggested using a wiki for students to collaborate on. This sounded brilliant. After all, many colleges are beginning to use wikis or similar message boards for class discussion, I could embed my research surveys, and make videos and resources easily accessible for my students. I added developing a wiki to the list of summer endeavors.

With definitive plans prepared for five PBL lessons and the class wiki set up, the year was looking promising. On the first day of school I explained to my class that throughout the year we would be learning a little differently than usual. I would be asking them to do something not many teachers have asked them to do previously, especially in their math classes. I would ask them to solve real life problems in pairs and present their solutions to the class. Yes, a math project. My students seemed intrigued yet reserved about the idea.

Once all their questions were answered about what the projects would be like, I continued to tell my students that not only will I be asking them to do projects but I will be studying them and giving surveys about the projects. Some students were confused by this. They worried the surveys would affect their grade. And wondered how truthful they could be on them. With all the logistics

out of the way it was time to start up the computers and get my class on the class wiki.

The wiki in theory was an awesome idea. While navigation and organization could always use more tweaking, I was ready for the kids to learn how to navigate the site, edit, and create pages. Our computers however were anything but ready. Maybe I set my hopes too high. I expected each student to have their personal login info with them and for it to work. About 50% had them and 1% worked.

After that class, I feverishly collected the remaining logins for next class. Expecting success in class number two was again, asking too much. Still only 1% of my students could log on to the network but no one could log on to their emails, which is how they access the wiki. Starting to panic, I quickly friended the Director of Technology. Why do the passwords work for logging on to the network but not their school email? Over the weekend he went back and forth with Google and found out that the password update over the summer only updated half of the student emails for the entire school and there is no way to know whose passwords are new for the year and whose need to still use last year's password. I return to my class with low spirits; we have been ironing out wrinkles for three class periods now, they are frustrated and want to give up but I won't let them. Everything for PBL is on that wiki. I inform my class that they

should try new passwords to log on to the network and last year's password for their email. Ten minutes go by when finally students are starting to cheer. Finally! They have accessed their emails. I give a few short directions to direct them to the wiki. I'm starting to feel hopeful, when every single student tells me they cannot locate the site. Ugh! Another road block.

Back to the tech guy. Access denied to all my students. We fight back and forth, trial after trial, hours of test emails, and restriction settings, only to conclude that my teacher email domain does not communicate with the school student email domain. I have never felt so defeated. After a week of wasted time to get the kids to their email they can't access the wiki or my surveys anyway. Long story short, after hours and days of more testing and tinkering finally my students get on the wiki and take the first survey.

I didn't think it would ever work but I put so much time in over the summer making the wiki and linking the surveys through Google docs I didn't want to give up on it. Plus, I really wanted my students to have the experience of creating and editing wiki pages, collaborating on a wiki, and posting homework assignments there too. The wiki is an important part of the PBL experience.

Finally, after a week or more of struggles, students learn how to access the wiki, make pages on the wiki, and to take the pre-survey. Next, present the first PBL problem. This problem, Tile My Bathroom, focused on teaching students to

use six problem solving steps that we would use throughout each PBL: Step 1. Identify and Select the Problem, Step 2. Analyze the Problem, Step 3. Generate Potential Solutions, Step 4. Select and Plan the Solution, Step 5. Implement the Solution, and Step 6. Evaluate the Solution. New math content was not a focus for Tile My Bathroom. Groups calculated area, cost to tile area, and cost of labor. For my students' first PBL experience I wanted them to learn the problem solving steps, not math content.

When I turned on the SMART board, the kids were all jazzed, I never use my SMART board. They have no idea what they are about to get into. I open the slideshow and tell them this slideshow will present the first PBL so they should pay close attention. Slide one: "Help me Prevent Disaster. Who can tile my shower wall for the best price and quality?" (Figure 1). Slide two: "Help avoid this! (pictures of mold and gross mildew)" (Figure 2). Slide three: Two pictures of my actual shower with dimensions of the wall and one sentence. "All you need to know." (Figure 3). They were so curious what was going to happen. They ewwed at the mold and called out, "Is that really your shower?" and "What are we to do?" I remained pretty unhelpful and referred them to the first slide that posed the question, "Who can tile my shower wall for the best price and quality?"

Figure 1. Slide one: “Help me Prevent Disaster.

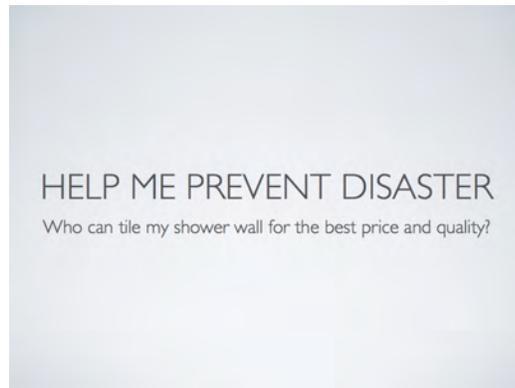


Figure 2. Slide two: “Help avoid this!

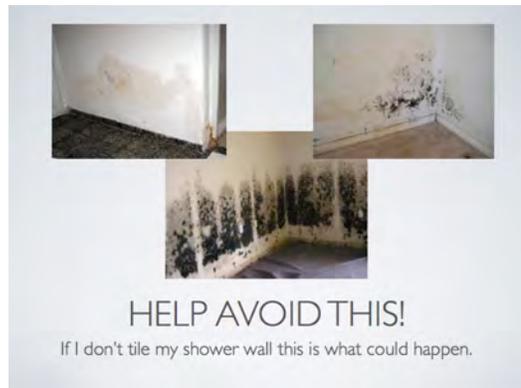


Figure 3. Slide three: “All you need to know.”



“Where do we start?” After I calmed the class, we started to brainstorm all their initial thoughts, ideas, questions, and concerns about the problem: how to tile the shower. The most prominent idea was which tile to use and where to find it. In my unhelpful role I told them to figure it out, use the computers in front of them, and I like the color blue. After about 15 minutes, I pulled them back together to see what they found out. Homedepot.com, Lowes.com, tile colors, tile material, the bare minimum. We held a small class discussion on what problem

solving steps they would be using and where they were going to solve the problem. Do you only need tile? You are the people doing the tiling. Do you need anything else? “Oh my god you want us to find out everything!” exclaimed Charlene. Again with the unhelpfulness I replied “Yes, you are tiling my real shower.” Back to work they went.

Now the kids are really thinking. Google search; How to tile a bathroom? For my students a whole new world opened up. There are so many details that need to be considered. By the end of day one I don't think a single group used a stitch of math. They all looked for tile colors and styles and the materials they would need to use in tiling. For homework each person in the group had to find out one new piece of information and add it to their group's wiki page.

Day two: kids get situated and we briefly discuss what they know. Many groups start to list tools and materials they will use, others talk about tile. The next question: “How much will you charge me to tile my bathroom?” “How are we supposed to know?” “It's up to you,” I say. Now they are finally thinking numbers. How much tile do we need? How much will it cost? Do we charge for tools, labor? Where do we find this? Students continue to solve these new problems with little to no guidance from me. They are starting to realize how complicated a simple sounding task can be. And how little I am going to tell them.

Holly calls me over to show me the Home Depot website and says, “I almost found what I need but the website doesn’t tell me how much? Can I call them tonight?” “Of course. If I was doing this I would have to go there or call so you should too.” A minute later she raises her hand again and says to me quietly “Can I call them now (holding her cell phone low, as to not let other students see)?” I pause and think for a moment, “Yes.” This was so exciting for me. My students are really thinking how to solve this problem. They really are getting all the details. Going to home improvement websites, calling stores, their parents, and even online help chats. “Tanja!! I love you!” calls out Charlene. I turn quickly, shocked she would call out like that. She waves me to her computer, “look at this.” Open on her screen is an instant messaging box “chatting Tanja, Homeimprovements.com” this group was giving the dimensions of the shower space to Tanja and the cost per tile and she was telling them the total area and how much it would cost. Genius! Well a little lazy but does it matter if they did the computations themselves or just that they found the answer on their own? I decide that finding this chat was a creative solution to their problem and say nothing but, “Alright, Tanja.”

As this class continues, each group reacts in totally different ways. I can clearly see that group dynamic is very important to the participation of all group members. One group has students that participate regularly, always do there

homework, and are self motivated. I can hear this group working hard on the problem. I hear them say things like “We will be saving 400 dollars,” or “This is so much more than I thought.” Another group that has two very outgoing students and two more introverted students does not interact much. The outgoing students, Antonio and Selena are talking to each other about the project but also about anything else they can think of - gossip, dance, shopping. This dynamic is leaving Onjoile and Otis to work on their own and report in or feel like they are not important. Antonio and Selena are working their head’s off. At the end of class Antonio says, “This class goes by really fast because there is so much to do and no time to do it in. I’m working so hard on this.” Selena says, “Ms. Hill, I feel tuckered out.” I know these two are working very hard on the project but I can’t help but feel like they think their other group members are inferior to them, thus completing all the work and not allowing the others to contribute.

After another class brainstorming session, this one about what they should include in their presentation, students start to compile and organize all the solutions they have found throughout the past three classes. Some students use PowerPoint and some use Prezi. Most, if not all, students have used PowerPoint in their history class so they are confident in creating a presentation with that tool. However, only a few have used Prezi before and have recommended it to their group. This is really cool because Karen, while not a math whiz is very good at

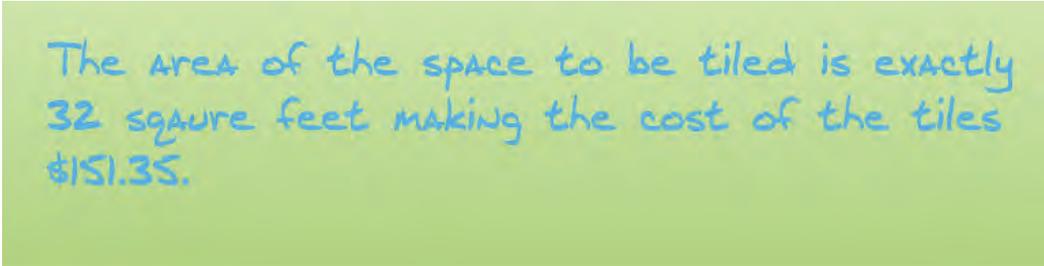
technology so she is showing her group how to use Prezi. They input text and photos with her leading the group.

By the next class, every group was prepared to show off how their group would tile my bathroom. They made a competition out of it. The winner presented the best price and tile I liked most. I never picked a winner, though, they were all so good. I was shocked that when I asked for volunteers every group wanted to go. I was even more shocked that every group was prepared. It is not often at my school that students meet deadlines.

Their presentations went surprisingly well. Of course there is room for improvement but each group was prepared and ready to go. We did have some glitches with absent group members and forgotten passwords but all in all it was more than I hoped for. I was very surprised how well behaved the class was for each group. They were silent and then even asked questions of each group at the end. Presentation times were also very reasonable. I encouraged each group to keep it under five minutes, but I didn't time them. If every student was present I think we could have had all groups present in one day. Along with short presentations however comes a want for more information. While each presentation hinted at research and thorough problem solving, does it count if you skip right to the answer when sharing your findings? All groups said they found the area of the shower wall that needed to be tiled (Figure 4) but only a few

explained how they found the area. All groups included other tools and materials that needed to be used but few explained each item's cost and with an explanation of what it is (Figure 5).

Figure 4. Area of Shower Wall



The area of the space to be tiled is exactly 32 square feet making the cost of the tiles \$151.35.

Figure 5. List of Tools and Materials



**What else do we
need
besides tiles?**

Virtex Brutus Tile Cutter
(Cuts 20" by 14"):
\$99.99

Acme Scrub Pad
Sponge:
\$2.79

Armstrong Vinyl
Tile Adhesive:
\$18.47

Marshalltown
(Notched Trowel):
\$3.99

Cement Mix
(2 of them):
\$23.38

Tilelab
(Grout and tile cleaner):
\$28.47

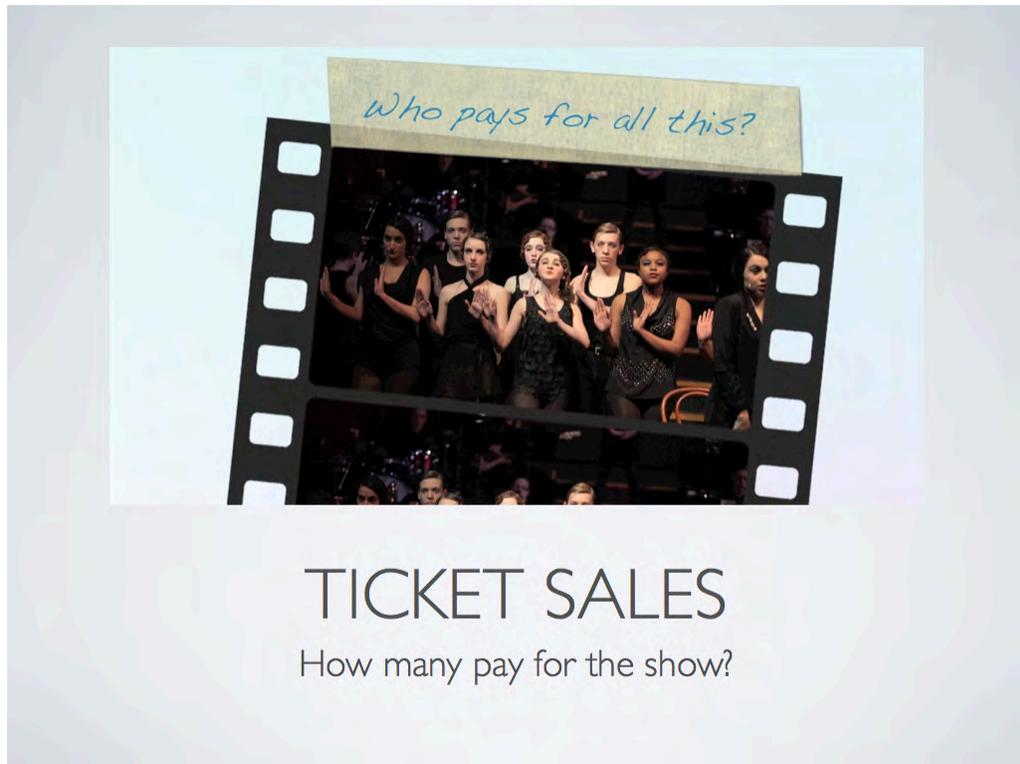
Tile Guard
(Grout line Whitener):
\$50.94

Super Thoroseal
(Waterproof coating):
\$37.99

Overall, first time presentations for first time PBL I would call it a success. Is there room for improvement? Absolutely. I hope they take my comments to heart and improve upon the depth of explanation and teamwork.

About a month later, I was ready for our next PBL, Ticket Sales. For this PBL student answered the question “How many tickets pay for the show?” To answer this question students must understand production costs, production incomes, profit, and graphing linear equations in standard form. I kicked off the project with an iMovie. In this movie were a vast array of photos from last year’s performances. I tried to pick photos that had students I thought might be in my class to pique their interest. The opening clip of the movie asks the question, “Who pays for the show?” (Figure 6). The final clip gives the answer, “the audience.”

Figure 6. Slide: “Who pays for the show?”



My class was stirring with the thought of doing a math project based on a performance that they had participated in. Their first question was “Where do we get the info from?” In the tiling PBL it was clear that looking in the Internet would get them far. However when the laptops were offered this time my students looked confused. I was just making the computers and Internet available. I was not implying that the answers could be found online.

Again after the video the first step in PBL is to identify problems. Through this open discussion of initial thoughts, problems, ideas, and concerns my students concluded that the first step was to pick a performance to research. Each group

had six types of performances to choose from: figure skating, dance, instrumental music, vocal music, theatre, or visual art. I assumed most would pick a show that they enjoyed most but I was wrong. After the first day of research when students listed possible expenses and some even spoke to their artistic teachers they thought that choosing one show over another would be easier. They determined that less expenses for the show meant easier. Once they settled on a show and spoke to their artistic teachers about the performance's income and expenses it was time to regroup as a class and put all their information into an equation in Standard Form and apply graphing linear inequalities to this real life situation.

I could tell that this step was going to be critical to their understanding of the math concept. Before I called the class together, many groups struggled to put the information they collected into an equation that expressed that the income from adult ticket sales and student ticket sales equalled the expenses of the performance. Jonathan could tell me exactly what the equation meant and would look like but when I asked him to write it he froze. Holly wrote the equation but could not express what it meant in words. And Punky wanted to write two equations. One for ticket sales equaling the expense and another for ticket sales equaling the number of seats in the theatre. After the class discussion, where I had these three groups explain where they were struggling or accomplished, Selena commented that, "This is a million times easier than the last project." For the rest

of the period, my students fine tuned their equations, organized data for their presentations, and discovered online graphing tools.

Figure 7. Drama- Charlene's Project

Charlene enters the classroom rushed with excitement. Ms. Hill is standing at the front of the room leaning on a podium, taking attendance.

Charlene: Ms. Hill I have to tell you this story! It's about my project!

Me: If this is about how you can't present today, I don't want to hear it.

Charlene: (with a shocked and apologetic voice) Ohhh no.

Me: Well then, continue.

Charlene: Well, I wanted to make my project special so I created a flyer to advertise for the Winter Concert. When I got home last night I nearly had a panic attack because I left the flyer on the kitchen counter but it was gone. (Charlene re-enacting the nights events) I called for my mom in a state of panic, 'Mom have you seen the flyer on the table?' (changing her voice to copy her mother's) 'Yes, don't worry, honey I'll be there. I took off work and put it in the calendar. December 20th I'll be there.' (ignoring her mother's response) 'Do you have the flyer?' (in her mother's voice) 'Yes, I hung it in the pantry next to the calendar.' (Laughing at her mother playfully) That's for a math project, it's not real!

Charlene, Karen, and Maddox's group really impressed me. They were getting so creative and going beyond what I had expected. Their presentation

included a concert flyer, sample concert music, and a bit of humor. These things were added bonuses. Overall, the group presentation's quality and thoroughness had increased from the previous PBL. Organization was very thoughtful, PowerPoint slides were easy to read, the equation included all expenses and incomes, the graph was a clear and correct depiction of the equation and solution to the problem, and all group members shared an equal part in the presentation.

For this round of presentations I included a panel of experts. Since this PBL required my students to research expenses and income for a school performance I thought it would be meaningful for the teachers who direct the shows to hear the analysis of costs and tickets sales. Also, presenting to the directors would make the research and analysis more meaningful to my students. While I am interested in their analysis for each show or concert, the directors are directly effected by how much profit each show makes.

Organizing the panel of experts was difficult and stressful on my end. But I think the feedback and experience it provided my students was worth the scheduling madness. Charlene admitted that she "dressed nicer" because the experts were there. Cherry found it "intimidating." "I liked that they were there because they weren't in our class and they didn't know what we were learning. So, I could get it out in my own words. That helped me understand it more," explained Holly. Justin also added, "[PBL] is a lot better this year. It's more fun

this year and easier. I'm more focused because of how it's organized and you run it."

The final PBL I used in my study was about cell phone plans and addressed the concept of solving systems of linear equations. In this PBL students had to research two cell phone plans and determine which was a better value for their personal phone usage habits. I of course introduced this problem to my students with a vague iMovie about cell phones. The movie did not provide any prices or plan types just the question "Which plan is best for you?" The next step was to brainstorm ideas on how to determine which phone, service, or provider is best. Students listed things like contracts, features, phone, long distance, and unlimited text. Brenda confessed, "I don't know anything about phones." And with that I sent them on their way to learn about cell phone plans.

A few moments into the work time Punky looked up from her computer and partner with her voice full of surprise and said, "This totally applies to my life ha ha ha ha, well not yet but when my parents kick me off of their plan it will." I replied not surprised at all, "good I'm glad you are learning something." Punky and Otis went back to work looking up providers, plan options, and comparing the possible choices to what they currently had on their cell phone plans. Punky is every math teacher's dream student. She loves learning and loves learning why math works. After two okay partnerships for Otis, a very quite introverted student,

I think Punky is the perfect match. Punky gives Otis the opportunity to think, talk, and do work. She values his contribution to their project and together they are solving the problems in front of them. Other partners Otis has had bulldozed him. He wasn't outgoing enough for them so they did twice the work instead of silencing themselves so they could listen to Otis's contribution. Punky has shown personal growth in cooperation, collaboration, and leadership during PBL tasks.

Antonio wears his heart on his sleeve. Never afraid to tell me what he is thinking. "I'm not really feeling this whole project thing," he says. This PBL has so many variables: voice minutes, texts, data, single line, family plan, provider, phone. My students are getting lost in the data. While this problem is more difficult than the last, it is an important lesson to learn that real world math is complicated. Half of the problem is sorting through the data you do not need. As a class we spent some time discussing what the variables in the equations represent, how to form the equations, and how to interpret the solutions. During this class discussion I gave my students constraints in order to eliminate variables. Each group had to choose to compare voice plans, voice plus texting, or voice plus data. I then provided instruction on defining the x variable as the number of overage minutes, texts, or data and the y variable as the total monthly bill.

Deacon is practically in tears over her solution. After solving her system of equation using substitution, she ended with $10=0$ (Figure 8). I can understand

why most people would be upset over this, however, I explained that not all real life problems have answers and that the two cell phone plans she was comparing will never equal the same price. I tried to further explicate my point by using another method of solving systems of equation, graphing. When we graphed her two equations, the lines were parallel (Figure 9). I continued the conversation by asking Deacon if the two lines will ever have a point in common? She responded through her teary eyes, “No.” Trying to console her and ease her tension I continued with, “ $10=0$ will never be true just the same as parallel lines will never meet, thus no matter how many minutes, texts, or data you use one plan will always cost less than the other. Deacon still looked miserable.

I wonder if there is anyway I can please this student? During traditional examples and book work she looks stressed and during PBL she moans and groans about using computers. Deacon feels, “that we waste time. I understand the concept so move on. [When we do PBL] I understand it more but I’m worried about cramming other stuff at the end of the year.” She dreads group work, technology, and presentations. I want her to enjoy PBL but at this time in her life I wonder if she can. I think she is stressing and focusing too much on SAT scores and not enough on life experiences.

Figure 8. Solving Systems of Equation using Substitution

For both equations 'y' stands for the total cost of that individual plan and 'x' stands for the number of extra minutes. To find out what plan would work better for me I had to solve both equations by using substitution.

1. $y=29.99+.45x$ (Basic)

2. $y=39.99+.45x$ (Talk)

2. $y=39.99+.45x$

1. $y=29.99+.45x$

$39.99+.45x=29.99+.45x$

$-29.99 \quad -29.99$

$10+.45x=.45x$

$-.45x \quad -.45x$

$10=0$

Figure 9. Solving Systems of Equations by Graphing

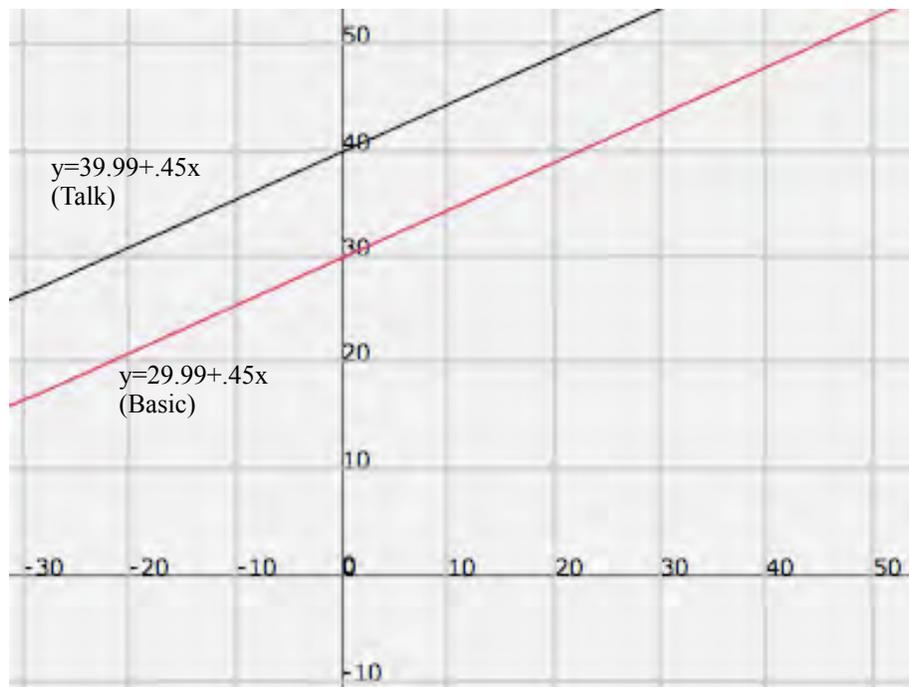
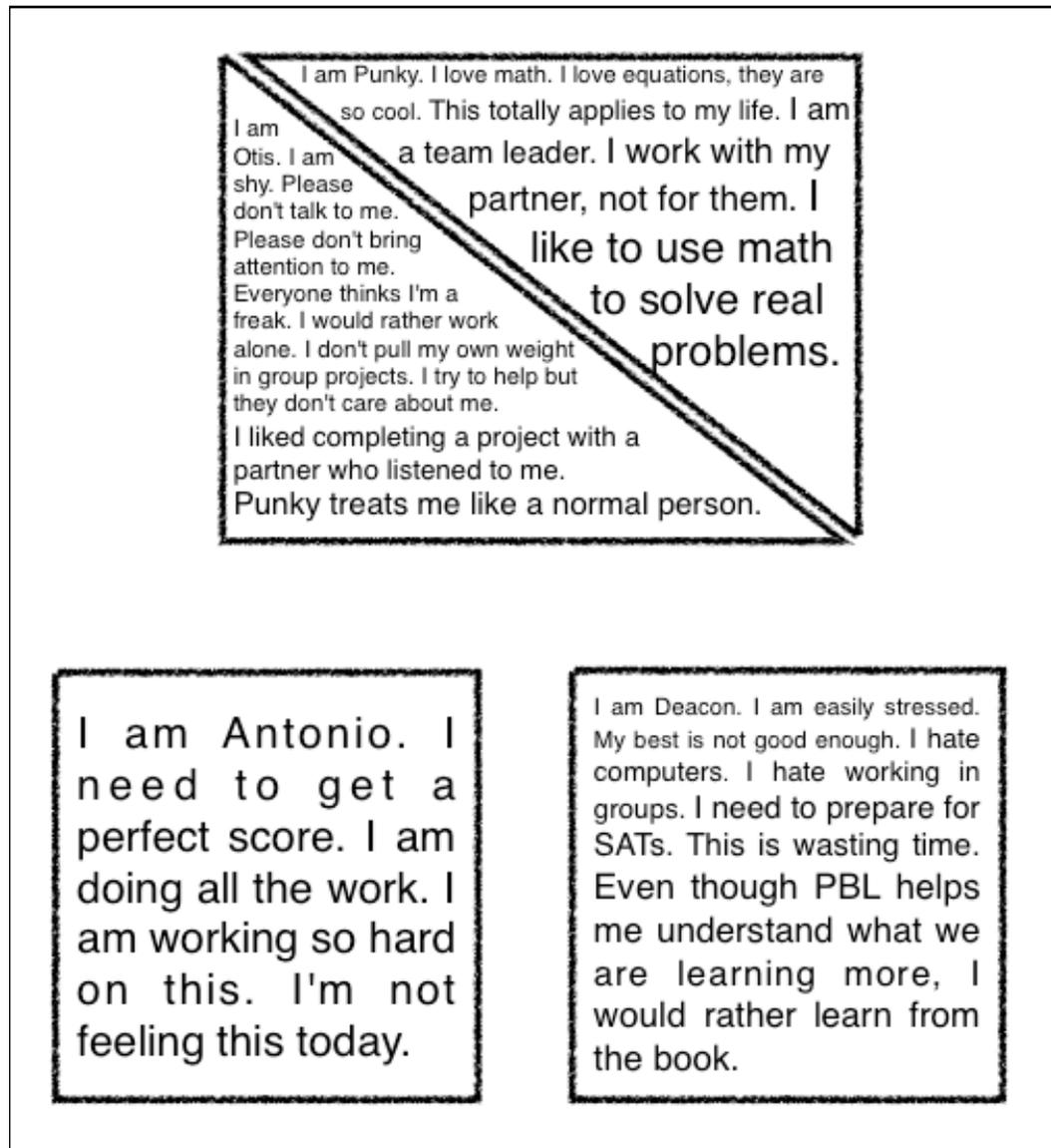


Figure 10. Pastiche- Four Students' Voices



Since this PBL task ran right up to winter break instead of presentations I asked my students to present their findings in a persuasive letter. I enjoy giving my students different ways to express their solutions: presentations and letters. Later in the year my students will create a game for the class to play. This letter could be addressed to anyone: Santa, Holiday Armadillo, Buddy the Elf, Mom, Dad, Aunt, Grandpop, best friend's parents. Throughout the letter each student needed to introduce the project, explicate the two cell phone plans they compared, show the math they used to find out which plan was better monetarily, include other reasons they might choose the plan or provider not based on money, and summarize their findings.

Students who followed the five paragraph outlined they created in class hit this letter out of the park. Students who did not follow the outline, fouled out. These students left me disappointed because I know how hard they worked in class. We spent three class periods on this PBL and some students turned in letters that were one paragraph. They left out all the details, all the math. These students were given the opportunity to resubmit their letters. I couldn't let them settle for less than mediocre work. After sharing feedback with each student and reviewing what they told me should be included in the letter, the new letters were much more desirable and could actually be used to convince a parent to change their child's cell phone plan based on their research.

My research collection period ended just in time for winter break.

Remembering the work my students produced during the three PBL tasks was an exciting task. The success we had with PBL was encouraging. I was encouraged to analyze the surveys and write up my findings. And I was encouraged to continue with PBL for the rest of the year. There are two more PBLs planned for the rest of the year: Angry Birds, an investigation of parabolas and PA Lottery, an investigation of combinations and permutations. This year, students asked for PBL and were glad to participate in it.

DATA ANALYSIS

Data Sources

Surveys.

Table 1

Pre- and Post-Survey Summary

13 participants

Question	Pre-Survey			Post-Survey		
	Dis-agree	No Opinion	Agree	Dis-agree	No Opinion	Agree
What I have learned in math up till now, will be useful to me in my life.	10%	40%	50%	12%	44%	44%
In math class, I often wonder why do I need to know this.	20%	20%	60%	23%	33%	44%
Working in cooperative learning groups helps me learn math.	30%	20%	50%	23%	0%	77%
Explaining ideas clearly is an important part of mathematics.	0%	0%	100%	11%	11%	78%
I can explain how I solved a math problem.	10%	20%	70%	11%	56%	33%

Pre-Survey.

On the first day of my data collection period, students responded to a 15 question survey. Each question was a five-level Likert item. (see Appendix D)

This survey gave me insight into my students' perception of the usefulness of

math in real life, their attitudes toward working in groups, and their ability to explain math and/or their problem solving process to others.

On that survey, 40% of my students had no opinion whether the math they learned so far in school would be useful to them in their lives. 40% agreed it would be useful. 60% of students wonder why they need to know most math topics. 50% of students said that working in groups helps them learn math. 100% of my students agreed that explaining ideas clearly is an important part of math. But only 70% felt that they could explain how they solved a math problem.

Post-Survey.

After the final PBL in my data collection period, students responded to the same 15 question survey as the Post-Survey. On that survey, 44% of my students had no opinion whether the math they learned so far in school would be useful to them in their lives. 44% agreed it would be useful. 44% of students wonder why they need to know most math topics. 77% of students said that working in groups helps them learn math. 77% of my students agreed that explaining ideas clearly is an important part of math. But only 33% felt that they could explain how they solved a math problem.

Field Journal and Reflective Blog.

While my students worked cooperatively on each PBL task, I wrote down what I observed. Some observational notes described students' interactions and break throughs, while other notes were quotes of dialogue between students or students and me. These notes helped me to capture candid pictures of my students throughout the data collection period. While my observation notes helped me capture the pictures of my students, the reflective blog helped me synthesize the pictures and see the patterns developing.

Student Artifacts.

Problem-Based Learning Evaluation Rubric.

In order to assess my students' PBL presentations equally and fairly, I graded them using a rubric (Appendix F). This rubric was given to my students before each PBL began so they could read and refer to the standards of quality of work expected. This rubric also allowed me to grade each presentation without bias and in alignment with preset standards. The rubric was split into four categories: Novice, Basic, Proficient, and Advanced. It assessed six criteria: Research quality, Strategies used, Organization of research, Communication, Comprehension, and Collaboration.

Students scored basic 4% of the time, proficient 71% of the time, and advanced 25% of the time on the first PBL task. On the final PBL task, students scored proficient 44% of the time and advanced 56% of the time.

Table 2

Evaluation Rubric Summary

Categories	First Task	Final Task
Novice	0%	0%
Basic	4%	0%
Proficient	71%	44%
Advanced	25%	56%

Self-Assessment for Group Work.

As a conclusion to each PBL task, each student was required to complete a Self-Assessment for Group Work (Appendix G). This assessment required my students to think about their contribution to the group, what they learned, and their likes and difficulties throughout the PBL.

73% of students reported having a positive experience in their group. Students reported equal work being done, friendly personalities, and helpfulness as reasons they enjoyed their group. Students reported their own independence

and personality, unrelated conversations, and communication outside of class time as reasons they did not enjoy their group.

The Self-Assessment gave me insight about what my students learned from completing the PBL task. 50% of students cited learning new skills that showed math comprehension. 30% of students cited learning new skills that are soft skills. 30% of students cited learning new skills that are technology related. And 65% of students cited learning new skills directly related to the PBL task such as tiling a bathroom shower or producing a school performance.

For each PBL, 50% of students said they liked the topic for the PBL and 50% said they liked using computers, working in groups, or presenting best.

Mid-Study Questionnaire.

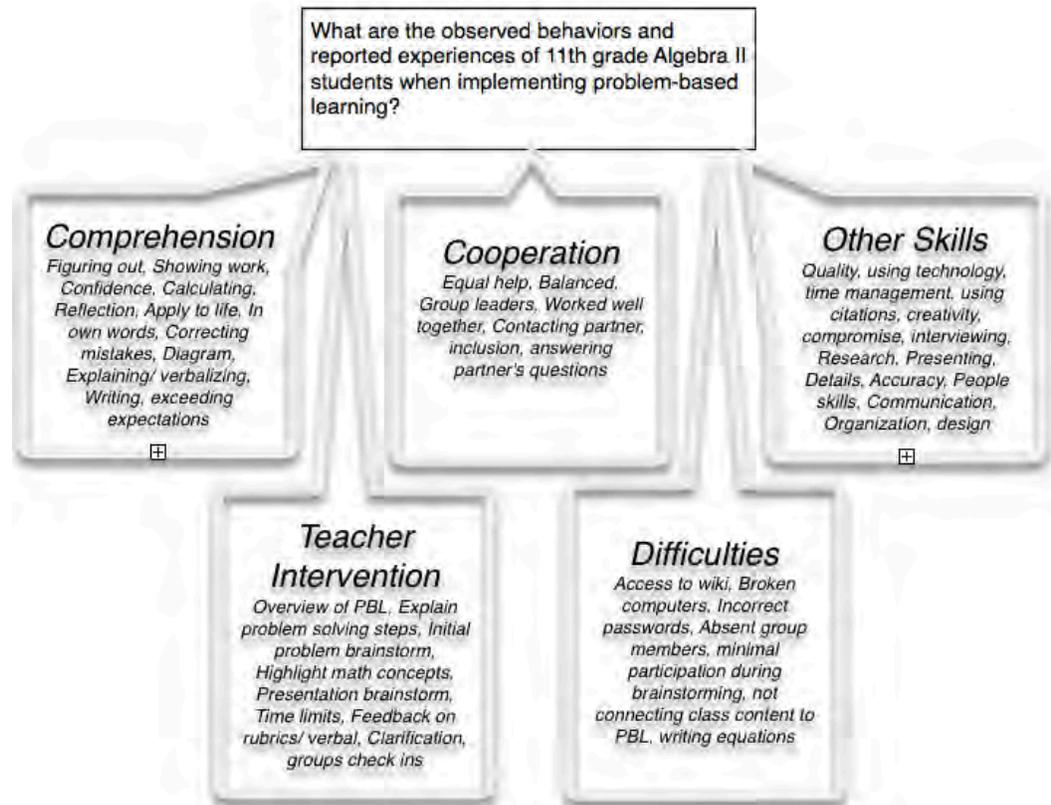
Mid-way through my data collection period I administered a mid-study questionnaire. This questionnaire helped me gain insight to my students opinions of Problem-based learning. This questionnaire asked students what was difficult, why they asked for my help, if giving an explanation to their solution provided them with a deeper understanding of the math they completed, and how they could improve their explanation of the solution. This information helped me understand if students were struggling with any particular step in the problem solving process. It also allows my students the opportunity to provide suggestions

on how they can improve for the next task as well as how I can improve the structure of the next task

Bins and Theme Statements

Towards the end of my data collection period, I reviewed everything I collected and began to code the data. During the coding process, I reread my data and each time something stood out to me I made a one or two word note next to the information. The codes were key words I used to describe what was happening in my classroom. For example, on a Self- Assessment for Group Work, Charlene wrote that she liked, “Making the poster/ flyer and making the prezi.” The codes I wrote next to this were “Not just math,” “other skills,” and “Tech.” Maddox wrote “I enjoyed their ideas and how if I needed help they helped me.” My code on this paper was “cooperation.” During the coding process, I started to see patterns or the codes repeating. As the patterns appeared, I documented similar and reoccurring codes and began to group the codes into bins. Each bin (Figure 11) is a collection of related codes. Once the bins were created, I summarized each bin by creating a theme statement. Each theme statement summarizes the patterns that my codes helped identify.

Figure 11. Bins Showing Related Codes



Theme Statements

1. Students demonstrated many cognitive skill levels through calculating, writing, explaining in their own words, formulating and solving equations, reflecting, and applying to a real life situation.
2. Through working cooperatively, students taught each other, learned together, identified problems, and created their own solution methods effectively.
3. Through the implementation of Problem-based learning, students practiced and developed other skills such as communication, organization, time management, reflection, compromise, research, attention to detail and accuracy, and using technology.
4. Teacher intervention is a key component of problem-based learning. Teacher intervention should be made at regular intervals in form of a class discussion or brainstorming and as needed for individual groups.
5. Difficulties students faced were gaining access to technology, having all group members present, formulating equations, translating class examples to PBL task, and working outside of class time.

RESEARCH FINDINGS

1. *Students demonstrated many cognitive skill levels through calculating, writing, explaining in their own words, formulating and solving equations, reflecting, and applying to a real life situation.*

Problem-Based Learning affords students the opportunity to demonstrate various cognitive skill levels through completing the task provided. Students' responses and participation traveled seamlessly up and down Bloom's taxonomy. For example in Ticket Sales, students demonstrated mathematical knowledge by multiplying the cost of an adult ticket by the unknown number of adult tickets sold (variable) to find the income from adult tickets, comprehension by graphing their linear inequality and shading the appropriate region, application by researching all of a show's expenses and possible incomes and making a linear inequality and graph to represent their solution, and evaluation by presenting their findings of a show's profit to a panel of experts who then required the students to justify their solutions and judge the show's profitability. Azer (2009) agrees that PBL promotes the development of higher-order thinking and Erickson (1999) suggests the PBL task be solved "using multiple solution strategies, multiple representations of the concept, and mathematical communication that includes explanation and justification" (p. 517). On the Self-Assessment for Group Work

Form, 50% of my students cited learning new skills that showed math comprehension.

Holly said, “I learned more elements to figuring out problems.”

Karen said, “I learned that I can actually do math.”

Justin stated, “I learned about measurements and dimensions. I also learned how to calculate the tile measurements to the walls of the shower.”

Otis learned, “how to calculate the cost of hourly wages” and “More about graphing linear inequalities and applying them to real life situations.”

Cherry shared, “I learned how to break down a situation in real life and put this [graphing linear equations] to use.”

Selena confessed, “There is a lot of math that has to do with putting on a show.”

Brenda learned, “We can apply math to our daily lives.”

During the first PBL task “Tile My Bathroom” students recalled the formula to find the area of a rectangular space, calculated the area of my shower wall, identified all the materials that were needed, demonstrated and explained how to find the cost of all needed materials, and applied their knowledge of area to

calculate the total cost and quantity of materials they would use. As my students worked towards completion of their tiling work proposal, they analyzed the data they collected and calculated, synthesized their findings through organizing, designing, and producing a presentations, and evaluated their work and their classmates work while watching the presentations and asking probing questions of each group.

Students showed similar signs of various cognitive skill levels during each PBL. In “Ticket Sales”, students applied graphing linear equations to a real life task. First, students analyzed through debate and research the costs of various school performances. Second, they organized the expenses and incomes for the performance into a linear equation in standard form. Third, they showed knowledge and comprehension for the mathematical concept by graphing their equation. And Finally, students evaluated their graphs to determine how many tickets would need to be sold to break even for the performance, make a profit, or make a loss.

Lastly, in “Which Plan is Best for You?”, students analyzed multiple cell phone providers’ many cell phone plans. To do this they compared and contrasted voice, text, and data plans, available cell phones, service coverage maps, and overall costs. Then, they separated the pertinent data from the irrelevant. With this data selected my students applied mathematical concepts such as writing linear

equations, and solving systems of equations to show which plan would cost less but give them the minutes, texts, and data usage most fitting for their personal needs. Their final task was to write a persuasive letter to convince a friend that they needed to change their plan or prove the plan they are currently using is the best for their needs. These three tasks follow Erickson's suggestions for problem-based learning tasks (1999). He suggests the problem lend itself to "using multiple solution strategies, multiple representations of the concept, and mathematical communication that includes explanation and justification" (p. 517).

2. *Through working cooperatively, students taught each other, learned together, identified problems, and created their own solution methods effectively.*

In order for students to achieve at the highest level possible, students should be grouped together with like achievement levels and each problem should allow for "various solutions at diverse levels" (Kwon et al., 2006, p. 53). Prior to each PBL, I carefully selected the groups my students would be working in to complete the task. Punky and Otis are a good example of two students who have similar achievement levels successfully working together. However, I am uncertain if these students worked well together because of their achievement levels or

because of personality. In previous groups, Punky was successful while working with students of similar achievement level, but Otis was not. I believe Punky and Otis were successful not because they are both good at math but because Punky gave Otis the opportunity to think, talk, and do work. She valued his contribution while others' did not. Otis is a shy, quiet student who did not need to be paired with someone of his intellectual equal but someone who would listen and collaborate with him. According to a study of middle school students conducted by Cerezo (2004) successful collaboration contributes to perceived success at finding a solution.

Through the trial and error of student groups I have found that while grouping students with similar achievement levels was successful, so was grouping students together who have different strengths. Karen provides me with an example of a student who is an average achieving math student but who excels at using technology. She taught the two other girls in her group, with confidence, how to input text, photos, video, music, and the general operation of the presentation tool Prezi. Karen's contribution to her group allowed her group's presentation to out shine their classmates. This group not only provided a successful solution to the problem but created a fun and interactive presentation unlike any other group. If placed in successful groups, I believe that students can become mathematics

investigators who are confident and capable problem solvers as Trafton and Hartman (1997) suggest.

In Cerezo's (2004) study of middle school students in a PBL environment, the students acknowledged their need and want to socialize while learning. These students reported that successful collaboration contributed to their perceived success at finding a solution. My students shared similar feelings. On the Pre-Survey only 50% of my students said that working in groups helps them learn math. But after three PBL tasks, 77% of my students said that working in groups helps them learn math. This means that students who originally preferred to work alone later found value in having a partner or other group members. One example is Punky. She originally said, "I just don't like working with people because I'm a total control freak and I enjoy my process." She then later commented, "I liked the teamwork. Selena was such a team player. It was great." This student changed her mind about group work because her partner contributed equally to the project and they both possessed equal motivation to complete the task at their highest ability.

Other students expressed their feelings toward working in groups on their Self-Assessment for Group Work. 73% of my students reported having a positive experience in their group. Students reported equal work being done, friendly personalities, and helpfulness as reasons they enjoyed their group.

Charlene said, “I really enjoyed my group, we all worked and communicated with each other. (I would love to work with them again on another project!)”

Karen said, “My teammates Justin and Charlene were splendid and we had fun while we worked.”

Selena said, “I loved Punky! She worked super hard, our personalities balanced each other out.”

Negative feelings toward group members were expressed by 27% of my students. Through their negative expressions, my students still suggest that socializing and a safe group environment is necessary for perceived success.

Maddox said, “I didn’t enjoy how people would have personal conversations.”

Deacon said, “I’m a very independent learner so working with others can frustrate me, not proud of it.”

Selena said, “Maddox did occasional work but gave me a lot of attitude about everything and Otis was just quiet.”

- 3. Through the implementation of Problem-based learning, students practiced and developed other skills such as communication, organization, time management, reflection, compromise, research, attention to detail and accuracy, and using technology.*

Pearlman (2006) insists problems be designed to meet state content standards and 21st century skills, including collaboration, critical thinking, written communication, and oral communication. Group work in a PBL classroom serves as more than a time to find the answer, permitting students to work as part of a team, to conduct research and explore the problem, and to develop patience and persistence, all while expanding their problem solving skills and mathematical knowledge. Throughout the data collection period, my students demonstrated many signs of developing 21st century skills. On the Self Assessment for Group Work Form, 30% of my students cited learning 21st century skills.

Cherry said, “He was an easy person to work with. There were little to no distractions. We got done what was needed quickly.”

Antonio said, “I enjoyed the equal contribution from everyone and pleasant attitudes.”

Deacon said she learned, “How to deal with others better.”

Jonathan said he enjoyed, “Presenting. Just getting up in front of the class.” and “I found the gathering of all the costs and materials needed difficult because you couldn’t miss anything, then it wouldn’t be as accurate.”

Charlene said she likes class because, “it’s teaching us life skill as well as math.”

Students demonstrated the development of research skills and use of technology. Pearlman (2006) says a students can research any topic and communicate with experts and teachers given a computer with internet access. During the first PBL students hesitantly began research for tiles using Google search engine. As they discovered the need for more tiling supplies, tools, and information about each tile their resources evolved quickly. Beginning with Google, leading them to home improvement websites and online stores to calling their parents, and online chats with experts. Antonio sums up his daily activities with, “This class goes by really fast because there is so much to do and no time to do it in. I’m working so hard on this.”

Using unique research methods in the first task helped my students immediately think abstractly when researching ticket sales. On the first day of research for “Ticket Sales” students quickly concluded that Google would not be a useful tool but interviewing theatre, dance, and music teachers would be the

research method most helpful. On the next day of research, students returned to their artistic teachers for more detailed information on expenses to produce the play, dance performance, or concert. Students also considered specific websites, instead of using a general Google search, to find cost of printing posters or buying tickets to attend the show. Murray-Harvey et al. (2005) offer that involvement in researching authentic problems allows teamwork and problem-solving skills to be developed, while also learning core subject matter.

In addition to learning or developing collaboration and research skills, problem-solving, and mathematics content, students learned to use technology and computers in new ways. Using the Internet to conduct research is common practice for students, however students need not only find data but assess sources for reliability and accuracy of data. Other than as a research tool, students used computers and the Internet to access a wikispace where they communicated and collaborated with their partners, collected and organized data, and submitted assignments. My students used PowerPoint, Prezi.com, and similar presentation programs to teach each other how to create a presentation and how to embed photos, music, and videos into their presentation to make it an interactive experience. 30% of my students cited learning new skills that are technology related on the Self-Assessment Form.

Deacon said, "I learned more about Prezi.com"

Maddox commented that, “I liked making our presentation because I learned how to use Prezi.”

Antonio said, “I liked creating the Prezi because I never got to use it and it was interesting.”

Holly liked, “MAKING THE POWERPOINT. I like my style [humor]. I liked how my ppt. [PowerPoint] turned out.”

Punky listed, “Graphing on a computer,” as a difficulty she had.

Cherry said, “I learned how to graph online.”

Charlene exclaimed, “TANJA! [online expert chat]. She’s beautiful and helped us a lot with conversions.”

4. *Teacher intervention is a key component of problem-based learning. Teacher intervention should be made at regular intervals in form of a class discussion or brainstorming and as needed for individual groups.*

The teacher’s purpose is to facilitate, question, and guide learning, not be the sole knowledge holder and provider (Flores, 2006; Nugent, 2006). Throughout each PBL task student groups solved problems through their own problem solving methods. As the facilitator I posed questions and guided learning for each group. I

tried to be “less helpful” as encouraged by Meyer (2010). Meyer believes this allows students to think for themselves without being inundated by pre-planned formulas, methods, and solutions.

During the cell phone task, once two groups asked similar questions regarding writing the equations I convened the class to have everyone discuss how to form the equations. Bringing the class together for discussion allowed me to choose students who could help explain to their classmates and guide each other instead of me imparting all the knowledge. Clarke and Roche (2009) and Trafton and Hartman (1997) agree that during the clarification process, the teacher should highlight the main mathematical concepts of the lesson so all students understand them. It is a teacher’s responsibility to not force learning but to facilitate, guide, and interpret the group’s suggestions (Dewey, 1938). While together as a class, I could interject small nuances to the mathematical concepts while students did the bulk of explication. For example, during Tile My Bathroom, Karen explained to the class how to find the area of the surface that needed to be tiled. She outlined the picture of my shower to show the dimensions and explained that the length times the width would equal the area. However, during her explanation she did not understand that the measurement unit would change from inches to inches squared. At this point, I interjected. Using her picture of the shower I drew

squares to visually represent multiplying length times width makes inches squared.

Students confirmed their need for further explanation in regards to math content. On the Mid-Study Questionnaire, seven out of 11 students expressed their varying needs of further explanation.

Maddox admitted, “We weren’t sure how to set up our equation.”

Holly asked for “clarification on what we needed for our equation.”

Selena said, “it was more so to see if we were doing it right, rather than to ask where to start or something just to know we were doing it right before moving on.”

- 5. Difficulties students faced were gaining access to technology, having all group members present, formulating equations, translating class examples to PBL task, and working outside of class time.*

Many complications and difficulties plagued my class throughout the eight week data collection period. A constant issue my students faced was access to technology and the working state of computers in our school. Pearlman (2006) says a computer with internet access allows students to “research any topic,

communicate with experts and teachers, write journals and reports, and develop presentations” (p. 5). I spent the countless hours troubleshooting my students’ access to the wiki, then weeks troubleshooting students’ school network and email passwords, and finally fighting an ongoing battle with laptops and desk tops loading slowly, not connecting to the internet, and not functioning in various other ways. In order for PBL to be connected to the real world, computer and internet access was critical to the process.

Another major hurdle my students overcame daily was the attendance of their group members. My students struggled with who physically had notes, handouts, and research. I tried to combat this problem by requiring daily wiki posts from each group. If my students use the wiki like notebook paper then each member would have all the data they collected at home and at school the next day. Using the wiki effectively is an important part of the PBL process. According to Partnership for 21st Century Skills (2002), to be successful one must communicate and collaborate. The wiki provided a place for each group member to contribute ideas without the issue of lost or forgotten papers or absent students.

The last noteworthy difficulty my students encountered was converting in class, textbook examples to PBL tasks. During the “Ticket Sales” PBL a few of the groups could verbally explain how the equation should look, while other groups could write the equation in standard form $Ax+By=C$ but could not

describe it verbally. Jonathan could tell me exactly what the equation meant and what it would look like but when I asked him to write it he froze. Holly wrote the equation but could not express what it meant in words. And Punky wanted to write two equations. These three students were all correct in their own ways but I could tell that this step was going to be critical to their deep understanding of the math concept. After speaking to these three students I knew a class discussion would help iron out any confusion. Clarke and Roche (2009) and Trafton and Hartman (1997) agree that during the clarification process, the teacher should highlight the main mathematical concepts of the lesson so all students understand them. During this clarification process the three students I spoke with shared their ideas and the remaining students either listened and took notes for their own clarification or they helped explain the concept to their classmates. I mostly let my students explain and discuss together but acted as facilitator and catalyst to the conversation. It is a teacher's responsibility to not force learning but to facilitate, guide, and interpret the group's suggestions (Dewey, 1938).

THE NEXT STEP

Last school year was the first year I implemented problem based learning. I had only read a few articles on implementing PBL and best practices. I was so excited, I jumped right in. Due to my lack of lesson planning and me over estimating my students' ability to work independently, PBL quickly went from an exciting, fun math project to a dreaded, painful experience. Although I gave up on PBL halfway through that school year, I did not give up on it completely.

I assessed my failure and short comings in implementation and began conducting more thorough research on the topic. With my literature review complete and five detailed lesson plans ready for the year, I had my confidence back for implementing PBL.

Although this continued research and careful lesson planning occurred before my thesis was complete, I think it teaches an important lesson about trying new teaching techniques. Since I believe in PBL, giving up was not an option. Since the first effort of implementation did not go as expected, more research on the best practices for the technique were needed.

As for this research specifically, I look forward to sharing my findings with my colleagues. I have been boasting about PBL from day one and now can finally share the outcomes of implementation. I plan on developing PBL tasks for

my Algebra I classes and hopefully collaborate with the other teachers in my school to introduce and create PBL tasks for their classes as well.

While sharing my journey and successes with teachers in my school is exciting, I want to share my exciting experiences with the world. The first step I have taken in this endeavor is sharing my PBL lesson plans with a published author and PBL enthusiast. I first was introduced to Jane Krauss through a book she wrote on designing PBL tasks. I then connected with her through Classroom 2.0's forum while creating my Professional Learning Network last summer. And most recently earlier this school year she contacted me through my blog, moravian PARKING, to ask me questions about my PBL lessons and grading rubrics.

The next steps in my endeavor are presenting my teacher action research and submitting my work to be published. I will be presenting my teacher action research at USD Action Research Conference in San Diego this April and plan on enrolling in MEDU 710 next year to learn how to alter my research, data, and findings into a short but informative article appropriate for publication in education journals.

Finally, over the past four years at Moravian I have developed my interest for technology, teacher action research, and publication. When I started the program I never considered writing to be published or technology to be more than

kitsch. The most common topics of conversation between me and my colleagues are my ideas, uses, and love for technology. In the near future, I would like to phase out teaching math to students and phase in teaching technology and planning lessons with technology with teachers.

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APPENDICES

A. Human Subjects Internal Review Board Approval



April 26, 2011

Jamie Hill
43 S 2nd Street
Emmaus, PA 18062

HSIRB proposal by Jamie Hill for Richard Grove

Dear Jamie Hill:

The Moravian College Human Subjects Internal Review Board has reviewed your proposal: "Problem Based Learning: Math Made Relevant." Given the materials submitted, your proposal received an expedited review. A copy of your proposal will remain with the HSIRB Chair.

Please note that if you intend on venturing into other topics than the ones indicated in your proposal, you must inform the HSIRB about what those topics will be.

Should any other aspect of your research change or extend past one year of the date of this letter, you must file those changes or extensions with the HSIRB before implementation.

This letter has been sent to you through U.S. Mail and e-mail. Please do not hesitate to contact me by telephone (610-861-1379) or through e-mail (browerg@moravian.edu) should you have any questions about the committee's requests.

George D. Brower
Chair, Human Subjects Internal Review Board
Moravian College
610-861-1379

B. Principal Consent Form

August 26, 2011

Dear [REDACTED]

I am currently taking courses toward my Master's degree at Moravian College. The course is part of a teacher action research program that encourages self-reflection and reading current research to help improve our own teaching practices. The Moravian College program helps me find the most effective ways of teaching and provide the best environment for my students.

The work required for the course involves conducting a systematic study of my own teaching. The focus of my research this semester is the observed behaviors and reported experiences of 11th grade Algebra II students when implementing problem-based learning. I hope to find the effects of problem-based learning on student written communication skills, student ability to think independently, and to expand student understanding of math's purpose.

I will be gathering data to support my study through the use of a double entry field log, conferencing with students, and student self-assessments and surveys. I will be collecting data in the months of September, October, November, and December. I will only use data collected from students who have been given consent to participate in the study in any written reports of my research. All of the students' names will be kept confidential as well as the names of teachers, other staff, and the school. Only my name, the names of my sponsoring professors, and Moravian College will appear in this study. All research materials will be kept in a secure location in my home and all data gathered during the study will be destroyed at the conclusion of the study.

All of the students in my classroom will receive the same instruction and assignments as part of the Mathematics curriculum. Participation in this study is entirely voluntary and will not affect the student's grade in anyway. Any student may withdraw at any time by writing me a letter or sending me an e-mail stating that he or she would like to do so. If a student is withdrawn from the study, I will not use any information pertaining to that student in my study and the student will not be penalized in any way.

If you have any questions or concerns about my research at any time, please contact me by phone at [REDACTED] or by e-mail at [REDACTED]. My faculty sponsor is Dr. Joseph Shosh. He can be contacted at Moravian College by phone at [REDACTED] or by e-mail at [REDACTED].

Please sign and return the second page of this letter. Thank you for all your help.

Sincerely,



Jamie Hill

C. Parental Consent Form

August 29, 2011

Dear Parent(s) or Guardian(s),

I am currently taking courses toward my Master's degree at Moravian College. The course is part of a teacher action research program that encourages self-reflection and reading current research to help improve our own teaching practices. The Moravian College program helps me find the most effective ways of teaching and provide the best environment for my students.

The work required for the course involves conducting a systematic study of my own teaching. The focus of my research this semester is the observed behaviors and reported experiences of 11th grade Algebra II students when implementing problem-based learning. I hope to find the effects of problem-based learning on student written communication skills, student ability to think independently, and to expand student understanding of math's purpose.

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All of the students in my classroom will receive the same instruction and assignments as part of the Mathematics curriculum. Participation in this study is entirely voluntary and will not affect the student's grade in anyway. Any student may withdraw at any time by writing me a letter or sending me an e-mail stating that he or she would like to do so. If a student is withdrawn from the study, I will not use any information pertaining to that student in my study and the student will not be penalized in any way.

If you have any questions or concerns about my research at any time, please contact me by phone at [REDACTED] or by e-mail at [REDACTED]. My faculty sponsor is Dr. Joseph Shosh. He can be contacted at Moravian College by phone at [REDACTED] or by e-mail at [REDACTED].

Please sign and return the second page of this letter. Thank you for all your help.

Sincerely,



Jamie Hill

D. Pre- and Post-Survey

Problem-Based Learning Pre-Survey

Ms. Hill
Algebra 2 CP

Please rate each response on a scale of 1-5. 1 being strongly disagree and 5 being strongly agree.

1. What I have learned in math up to Algebra 2, will be useful to me in my life.

Strongly disagree 1 2 3 4 5 Strongly agree

2. In math class, we do problems that relate to my life.

Strongly disagree 1 2 3 4 5 Strongly agree

3. I struggle to understand why we learn math.

Strongly disagree 1 2 3 4 5 Strongly agree

4. In math class, I often wonder why do I need to know this.

Strongly disagree 1 2 3 4 5 Strongly agree

5. I would like the teacher to tell or show me how every concept I learn in math can relate to my life either now or when I get older.

Strongly disagree 1 2 3 4 5 Strongly agree

6. I can apply what I learn in math class to real life situations.

Strongly disagree 1 2 3 4 5 Strongly agree

7. Working in cooperative learning groups helps me learn math.

Strongly disagree 1 2 3 4 5 Strongly agree

8. I struggle to apply what I learn in class to new problems on my own.

Strongly disagree 1 2 3 4 5 Strongly agree

9. I am confident in the work I complete in class and outside of class.

Strongly disagree 1 2 3 4 5 Strongly agree

E. Mid- Study Questionnaire

Problem-Based Learning Mid-Study Questionnaire

Ms. Hill
Algebra 2 CP

Please answer the follow questions.

1. In the past, how much of what you learned in math class connected to real life situations?
2. Do you think you could apply the process and solution from the PBL to another problem on your own? Why or why not.
3. How does the PBL help you understand math concepts better?
4. During the PBL, did your group need help from the teacher?
5. Explain why your group did or did not need help.
6. Did you require more help or less help from the previous assignment? Why?
7. Do you prefer to work and learn on your own (in groups) or with the teacher at the board?

Explain why.

8. Was explaining your process and solution for the PBL difficult? Explain why or why not.
9. Did explaining your process for solving the PBL help you understand the answer more?

Explain why or why not.

10. Compared to the previous assignment, was explaining you process and solution more or less difficult? Explain why.
11. If a stranger read your process and solution to the PBL would they understand how you came to your solution? How could you make it better?

Name: _____ Date: _____

F. Problem-Based Learning Evaluation Rubric

Criteria	Novice = 1	Basic = 2	Proficient = 3	Advanced = 4
Research quality	Numerous inaccuracies with little if any detail	Inconsistent accuracy but some level of detail	Accurate and competent with relevant detail	Highly accurate and sophisticated with explicit detail
Strategies used	At least one acceptable strategy attempted	At least one acceptable strategy correctly applied	Several high-quality strategies applied	Numerous complex and sophisticated strategies applied
Organization of research	Confusing and clumsy organization	Simple but acceptable organization	Reflective organization demonstrates solid planning	Intuitive organization displays complex and perceptive thinking
Communication	Ineffective and vague	Superficial quality may lead to some confusion	Competent and effective communication	Precise and nuanced communication shows high level of sophistication
Comprehension	Little if any understanding demonstrated	Limited, superficial understanding demonstrated	Demonstrations of accurate and thoughtful understanding	Numerous demonstrations of profound and perceptive understandings
Collaboration	Little evidence of collaboration	Intermittent displays of collaboration	Thoughtful collaboration demonstrated	Highly effective and synergistic collaboration

Adapted from Problem-Based Learning for Math & Science:

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G. Self-Assessment for Group Work

Name: _____ Date: _____

Self-Assessment for Group Work

- Were all project objectives and criteria met?
- Were the parts done correctly and accurately?
- Were all written aspects of this project done well (correct spelling and sentence structure, neat and organized)?

Superior: (E)	Satisfactory: (S)	Need for Improvement: (N)
My work is superior/excellent. I made many positive contributions to the team effort. I encouraged other team members and gave them assistance when they needed help. I was instrumental to my team's success.	My work was complete, correct, and accurate. I made some positive contributions to the team effort. I encouraged at least one team member. I helped my team to succeed.	I could have done better. I did not encourage others. I did not worry about my team. I didn't really contribute much to the team effort.

Explain the reasons for the grade you gave yourself in four or five complete sentences. Which team members were most helpful? Which were not?

What new concepts did you learn from doing this project?

Did you find any part of this project difficult? If so, which part?

Was there any part of the project you liked best? Why did you like that part?

What did you enjoy or not enjoy about working with your teammates during this particular project?

How do you feel about the class right now?

What do you think we can do to improve this class?

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