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The Effects of Problem-Based Learning: A Literature Review

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THE EFFECTS OF PROBLEM-BASED LEARNING: A LITERATURE REVIEW

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Abstract

This thesis reviews the existing research of problem-based learning (PBL) and its implementation at a secondary level. The goal of the research is to determine if PBL should be implemented with students in a secondary math classroom. The author reviews the effects of PBL on student learning, as well as identifies various implementations of the method including tools that can be added to the method. The challenges of PBL for both the student and the teacher are explained and implications for educators are described. Since its initial introduction in medical school in 1969, PBL has continued to expand to undergraduate programs and secondary classrooms. Prior to complete implementation of a new method of learning, teachers should consider the impact of PBL on students assessment results, retention, skills beyond content knowledge, and satisfaction with the method. The author will explain how the challenges to PBL can be overcome with proper training and additional tools.

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CHAPTER I: INTRODUCTION

I have taught high school math for a total of four years, but I have been a math student for over 21 years. Through personal experience as a math student and the experiences I have in the classroom, it is clear that math is often seen as a complex challenging subject that only "math people" can be successful at. This stems from the belief that problems in math have one perfect way to solve them, and you have to memorize the formula or process to be successful. In life, problems rarely have only one exact solution with one perfect path to solving. I have heard the question, "can you just tell me how to do it?" too many times in my classroom, and this pushes me to question if there is another method of teaching that helps students to build skills that enable them to problem-solve and be independent learners.

In my school, we have recently implemented a new curriculum that utilizes a collaborative format alongside problem-based learning (PBL) that allows students to construct knowledge together with the teacher as a facilitator. This new curriculum has a goal to help students become problem solvers and independent learners, but the new curriculums has resulted in a lot of push back from students as they continue to be stuck in a place of informational absorbers, with a view of math that focuses on memorization and process repetition. The term PBL has been given to us teachers as what is best for student success and learning, but there has been little to no research provided to support this shift in our school. As educators, it is important to use research based practices to ensure our students receive the best instruction available. For this very reason, I find it important to investigate PBL and the effects it has on student achievement.

History of Problem-Based Learning

PBL is based on the theory of constructivism in which learning happens through the construction of knowledge (Celik, Onder, & Silay, 2011). Specifically, constructivism emphasizes that students learn new information through the active engagement in learning environments through a student-centered approach (Gijbels & Loyens, 2009). PBL applies the theory of constructivism by utilizing prior knowledge and skill to build new learning and reduces misconceptions through individual and group work (Celik et al., 2011). Pecore expanded on this by stating, "In theory, students become less dependent on teachers and texts for answers, and more reliant on the content knowledge they acquire through personal research, their own judgement and common sense" (2013, p. 9).

PBL began at McMasters University faculty of medicine in 1969, where instructors introduced a new method of learning that emphasized the integration of basic knowledge and skills in the clinical field (Barrows, 1986; Woltering et al., 2009). After the initial introduction of PBL, the approach was implemented in other medical fields and schools including nursing, pharmacy and dentistry in the 1980s and 1990s across North America and Europe (Savery, 2006; Wilkinson, 2009). Since this time, PBL has been implemented in schools ranging from elementary level to graduate levels (Torp & Sage, 2002). In recent years, research has emerged specifically on the implementation of PBL at the secondary level. In 1997, Dods investigated the impact of PBL on secondary bio-chemistry student learning. Further research indicates the effects of PBL have been investigated in a variety of different subject areas at the secondary level including technology, math, agriculture, science and social studies (Akti & Duruhan, 2019; Fatade, Mogari & Arigbabu, 2013; Nakhunu & Musasia, 2015; Wirkala & Kuhn, 2011; Wong & Day, 2009). While PBL research indicates a presence at the secondary level, the body of research is limited.

What is Problem-Based Learning?

While there is no definitive definition of PBL, teachers who have utilized this method in their classrooms share multiple commonalities. The basis for PBL as described by Wirkala and Kuhn (2011) is a method that allows students to engage in a problem, without prior preparation, that stretches their current knowledge. This requires students to extend what they currently know and understand about the topic and produce a solution to the problem. These problems do not have a specific clear cut answer which encourages students to ask questions, work with their classmates and look for more information.

While the overarching idea of PBL is a problem provided to students that encourages ownership of learning, there are more specifics to the method as provided by other researchers. There are two common breakdowns to PBL that include either three phases or five phases. The three phase breakdown includes phases titled: "initial problem analysis, self-directed individual learning, and subsequent reporting phase" (Yew, Chng, & Schmidt, 2011, p. 451). Within each phase, there are specific tasks for the student. In the initial problem analysis phase, students are introduced to the problem and given the task of deciding the answer (Dods, 1997). Together, the students create a list of what is known about the problem and what they feel would need to be learned in order to generate an answer. Yew et al. (2011) agree with Dods (1997), and more specifically share that within this initial phase a hypotheses is generated. During phase two, self-directed individual learning, students take time to study the problem further and answer questions within the list of need to know that was generated in the previous phase. The final conclusion stage of PBL is titled the reporting phase (Dods, 1997; Yew et al., 2011). Within this time, students report their individual findings to the group. If they finish and answer the question fully they move to a new problem, if not they repeat phases one through three. The five phase breakdown is similar, but includes phases of "(i) identify the problem, (ii) make assumptions, (iii) formulate a model, (iv) use the model and (v) evaluate the model" (Fatade et al., 2013, p. 35).

To summarize, PBL utilizes problems with multiple different solutions or avenues to arrive at a solution. PBL is student-centered and focuses on the learning process and less on the actual solution (Wan Husin et al., 2016). Teachers who implement this method can do so through a variation of either a three phase or a five phase model, both of which feature an ill-structured problem, time to research, and presentation of new knowledge.

Definition of Terms

For the purpose of this review a clear definition of both PBL and the traditional method of teaching is necessary. PBL is explained in detail above, but a clear definition of the method of learning is, a method of teaching and learning that engages students in a problem without prior preparation or sufficient knowledge of the students, thus requiring collaboration amongst students, self-directed learning and reporting to the class (Wan Husin et al., 2016; Wirkala & Kuhn, 2011; Yew et al., 2011). A large number of studies compare PBL to the traditional method of teaching, for this reason the traditional method will be defined as teaching methods which included direct instruction, demonstration and question-answer (Akti & Duruhan, 2019). Traditional method typically features lectures that are characterized by a teacher verbally transferring information they know directly to students who are held accountable through assessment that mainly measures their ability to recall content (Wong & Day, 2009). The traditional method is referred to throughout the paper using pseudonyms of: lecture-based learning, traditional lecture, conventional methods and traditional teaching methods.

Research Questions

As the body of literature is reviewed, the question that will guide the research is: Is problem-based learning an appropriate method to use in the secondary setting? Within the question the subtopics that will be addressed are: What are the effects of problem-based learning? How has problem-based learning been implemented in the classroom? What are the challenges to problem-based learning? Ultimately, before implementing a new method of learning, it should be ensured that it is best practice for students in that particular setting based on the research available on the topic.

CHAPTER II: LITERATURE REVIEW

Literature Search Procedures

To locate the literature for this thesis, searches of Academic Search Premier, EBSCO MegaFILE, Eric, and MathSciNet were conducted for publications from 1990-2019. The search was narrowed by only selecting peer-reviewed studies with a focus on PBL in a secondary setting to address the guiding questions. The key words used to search included, "problem-based learning," "secondary problem-based learning," "problem-based learning implementation," "problem-based learning effects" and "problem-based learning assessment." The following chapter is structured to review the literature on PBL in three sections in this order: What Are the Effects of Problem-Based Learning? And How Has Problem-Based Learning Been Implemented in the Classroom?, and What Are the Challenges of Problem-Based Learning?

What Are the Effects of Problem-Based Learning?

Through various studies it has become evident that PBL can have a variety of effects on students. Below are six different effects of PBL including assessments results, retention of materials, ability to apply learning to new situations, an increase in 21^{st} century skills, student satisfaction and gender differences in STEM field interests.

Assessment Results

Dods (1997) investigated both student understanding and retention of content in PBL as compared to content experienced with lecture based instruction. Thirty students at Illinois Mathematics and Science Academy enrolled in Bio-Chemistry participated in the investigation. Of the thirty students in the study, 29 were seniors and one was a junior with 15 males and 15 females. Each student served as their own control because they experienced both lecture based instruction and PBL. The instructor for the Bio-Chemistry course had taught the course for six years and had experience with PBL through participation in the IMSA Center for Problem-Based Learning.

The students in the study were delivered portions of content of the course as PBL. The instructor used lecture to precede the PBL lessons in order to provide scaffolding to students. The PBL lessons were initiated by an engager which was a scenario or question that draws student interest. They were then introduced to the problem and given the task of deciding the answer, which was limited to three options by the instructor. Students would then generate lists about the problem including what they knew and what they would need to know. Students would then research topics from the lists created and use that information to support their answer to the problem.

Instruments to collect data for the study were a student self-evaluation of depth of understanding, an instrument that measured the depth of understanding, as well as a student evaluation of the overall course satisfaction. The self-evaluation was administered before and after instruction. The survey contained terms that students were to rate their understanding of on a scale of zero to five. The terms included old, new and never seen before words. The terms that were old served as a control because they had been encountered by students in previous science courses at the school. The instrument that measured depth of understanding of the course content was evaluated by the instructor. The instrument gave students a term and instructed them to respond with their most in-depth understanding of the term. Finally, the student evaluation of the course overall was conducted on the last day of class. The evaluation included eight questions that students were instructed to rate on a scale of one to five. The results of this study showed that while lecture widened the coverage of content, understanding was significantly greater in PBL compared to traditional lecture.

Investigators Celik, Onder and Silay (2011), in a study with sophomore undergraduate students in a physics course, sought to investigate how PBL impacted the students' physics achievements. The participants included 44 sophomore undergraduate students from the Mathematics Education Department at Dokuz Eylul University. The students were selected randomly and divided into an experimental group of 20 students and a control group of 24 students. The control group was instructed through conventional teaching methods of lectures, while the experimental group was taught through PBL.

The PBL students were randomly assigned into groups and together were introduced to the problem and then tasked to do individual work. When they finished the individual work, they came back and presented the new information they learned to their group. To measure achievement of the students in the two topics covered, current and resistance, the researches created a physics exam. The exam included five structured problems and one open ended problem. The structured problems were assessed by a grading scale with three dimensions: understanding the problem, planning for the solution, and solving the problem. Before research began the students were given the exam and showed no significant difference in understanding between the groups. After the research there was a statistically significant difference between the two groups mean scores in demonstrating that the PBL was more effective on students' physics achievements.

Similar results were seen in a study by Akti and Duruhan (2019), which sought to reveal the impact of PBL on the achievement of sixth grade students in an Information Technologies and Software course. The study was conducted with 43 sixth grade students during the 2016-2017 school year. The students were put into equal sized experimental and control groups based on their first semester exam scores by matching students together. Within the experimental group the students were put into groups with similar academic levels. The students in the experimental group were instructed through PBL while students in the control group learned through the traditional teaching methods which included direct instruction, demonstration and question-answer. The total duration of the experiment was eight weeks.

Data was collected through an achievement test, a student performance evaluation form, a groupmate evaluation form and an interview form. The achievement test, developed by the researcher, administered as a pre-test and post-test, included 36 multiple-choice questions that underwent expert analysis to ensure validity. The student performance evaluation had a reliability coefficient of 0.988. The groupmate evaluation form asked each group member to evaluate two friends in their group. The interview form determined the opinions the students had about PBL. The data collected was analyzed both qualitatively and quantitatively.

Ultimately the results showed that students in the experimental group had increased results in comparison to the control group. The students in both groups showed growth from the pre-test to the post-test, but the numerical data results show a greater increase in the achievement of the experimental group. While this study had a small sample size, the researcher intentionally aimed to keep both the experimental group and control group at the same academic level to ensure the results reflect learning and not differences in students.

Akti and Duruhan (2019), Celik et al. (2011) and Dods (1997) all demonstrated through their studies that students in a PBL setting achieve higher in some way on assessments than those taught with the traditional method. Nakhanu and Musasia (2015) in their study on PBL and its effects on students' learning of linear programming arrived at similar results as well. The study utilized a form of PBL that used the origin test and extreme points technique to solve linear programming problems. The researchers were interested in the level of linear programming knowledge and skills achieved by learners taught using the origin test and extreme points technique, compared to those taught using conventional methods.

To explore this problem, the participants included students selected from all boys schools, all girls schools and co-educational high schools. Thirty total schools were included with ten schools representing each category. One class from each school was included in the study. A total of 745 students were in the experimental group and 757 students were in the control group. The study focused on linear programming, a mathematical concept with a goal of maximizing or minimizing linear variables while maintaining given linear constraints. The experimental group learned this concept through the origin test and extreme points technique, which is a form of PBL while the control group learned through the traditional method.

To measure the data, the instruments used were a Mathematics Achievement Pre-test (MAT 1) which contained five questions that measured linear programming prerequisite skills, and Mathematics Achievement Post-test (MAT 2) which contained five questions that measured students' performance in linear programming and optimization. MAT 1 was administered to participants prior to the instruction. The experimental group was given seven 40 minute PBL lessons on linear programming and the control group was given the same content using conventional methods. The total duration of the experiment was two weeks, and the final test MAT 2 was given within one week of the completion of the lessons.

To analyze the data the results of the pre-test (MAT 1) were compared between the experimental and control groups. There was no significant difference in the performance of the control group vs. the experimental group, although the control group did perform slightly better. The post-test (MAT 2) results were analyzed and revealed that the experimental group performed significantly better than the control. The experimental group acquired the linear programming skills better than the control group overall. The researchers concluded, "Results of this study show that learners taught using PBL achieved better results than those taught using conventional methods" (Nakhanu & Musasia, 2015, p. 73).

Overall assessment results give insight into the effects of PBL on students achievement, but assessments can measure a variety of different skills and leveled thinking of students. Ramli, Mohd, Ayub and Salim (2018) researched assessment results of students with more specifics in mind. "The purpose of this study was to investigate the effects of using problem based learning (PBL) strategy on students' performance (solving higher and lower order questions) compared to conventional instruction (CI) strategy " (p. 1). This study covered topics including Pythagoras theorem, transformations, solid geometry II and statistics. The participants included 62 female students from two different intact classes in the Seremban district in Negeri Sembilan. The classes were randomly assigned to either the PBL or the CI group. The experimental PBL group was comprised of 35 students and the control CI group was comprised by 27 students.

The study lasted eight weeks for each group, and the classes both had the same lesson structures, mathematical tasks and contact hours. A post-test that contained nine items that tested higher order thinking skills according to Blooms Taxonomy and nine items that tested lower order thinking was given at the end of the eight weeks. The test contained items that covered all four topics learned over the duration of the experiment. In order to increase the accuracy of the results of the post-tests for each student, the researchers used the students midyear test performance scores as a reference.

With the post-test containing items that assessed both higher order and lower order thinking, the researchers were able to analyze the effects of PBL on both types of questions. The results showed that the students in the PBL group, when compared to those in the CI group, did not achieve significantly different scores in solving lower order thinking questions. The PBL group achieved significantly better scores than the students in the CI group when the post-test was analyzed overall with both types of questions included. This shows, the students in the PBL group achieved significantly higher scores on the higher order thinking questions. Thus, PBL is an effective strategy to teach students higher order thinking skills.

While the studies listed above showed a positive impact of PBL on students assessment performance, these results of both Burris and Garton (2007) and Fatade, Mogari and Arigbabu (2013) showed PBL is not always positive. In their study conducted with secondary agricultural students in Missouri, Burris and Garton (2007) aimed to investigate how critical thinking ability and content knowledge was effected by PBL. The students selected for the experiment were selected purposefully as determined by criteria of instructors. Twelve teachers selected to participate based on teacher preparation program characteristics, meaning they had all received similar training in regards to methodology. Each classroom included was randomly assigned either the PBL group or the supervised study group. There was a total of 140 students with 77 students in the PBL group and 63 students in the supervised study experiment. The participants were 65% male and 35% female, aged ranging from sophomore students to senior students.

The experiment utilized a non-equivalent comparison group design with pre-test and post-tests. After undergoing a professional development study to prepare teachers to implement the assigned strategy for their class, six teachers taught a unit on quail habitat management through PBL and the other six taught the same unit through supervised study treatment. The data was collected through three different instruments. First, critical thinking ability was determined using a standardized tool for assessing developing critical thinking skills titled the Watson-Glaser Critical Thinking Appraisal (WGCTA). The content knowledge was measured by a quail management test that contained 50 selected response items related to the unit of study, developed by the Missouri Department of Conservation. The descriptive information about students including gender, grade level and academic aptitude was reported by teachers with a form developed by the researcher.

The results of this study showed that the students in the supervised study group actually scored higher on the critical thinking scores than those in the PBL group. The students in the supervised study performed better on content knowledge than those in the PBL group. Burris and Garton (2007) conclude, “While PBL students may have a deeper understanding of the material, that understanding is not represented at a content knowledge level” (p. 113). The different results of this study when compared to others on the effects of PBL may have been caused by the limited treatment period for the experiment. The experiment was only two weeks, so the exposure to the content may have been shortened for the PBL group since they were not familiar with the PBL process and took instruction to learn the process.

While Burris and Garton (2007) had results that showed lower achievement for students exposed to PBL, Fatade et al. (2013) showed higher achievement for students exposed to PBL, but a greater variation in the student performance. The study took place in Nigeria with a focus on low enrollment and poor performance of students in Further Mathematics. The research was guided by two different questions. 1. “Will there be any significant difference in the post-test achievement on the TMT scores between students exposed to the PBL and those exposed to the TM?” (p. 31). 2. “Will there be any significant difference between the post-test achievement scores on RCT between students exposed to the PBL and those exposed to the TM?” (p. 31). A clarification of the terms included in the questions is necessary, TM (traditional methods), PBL (problem-based learning), TMT (teacher-made test), and RDT (researcher-design test). To investigate those questions, the researchers included 96 senior secondary school year one further mathematics students with 52 males and 48 females. Purposeful sampling was used to select the two schools in participation and those two schools were randomly assigned the PBL method or the traditional method. The participants had ages with a mean of 15.4 years and 15.3 years.

Further Mathematics in Nigeria is a bridge for students between senior secondary school math courses and math in undergraduate programs. The experiment used a quasi-experimental design using pre-test and post-test non-equivalent control groups. The topics covered included indices and logarithms, sequences and series, and algebraic equations. The students in the experimental group were organized into six groups of seven students each. Students were given an ill-structured task as homework for each topic covered in the experiment. This task required students to prepare a presentation for the next class period by visiting the libraries and researching on the internet to find information. The students in the control group were taught the topics with the traditional method which included lecture and questioning methods. The learning was teacher-dominated and confined to the classroom. The study was three months in duration, and prior to instruction the classes were given the pre-test of both the TMT and the RDT. The TMT contained 10 essay questions based on the course content for the study. The RDT also contained essay questions with four questions focusing on the topics for the course.

The results of the study were analyzed based on the TMT and the RDT. With the TMT post-test results the students exposed to PBL had scores that were statistically significantly higher than those exposed to the TM. While the overall scores were significantly higher, the standard deviation for the mean of the experimental group was low on the pre-test indicating similar starting points for the students, but higher on the post-test 14.46 compared to the control standard deviation of 9.62, meaning the students in the class under experiment responded with more variability to PBL. The results of the RDT post-test scores were similar. The students in the PBL group showed a statistically significant difference in achievement than those students in the TM group, but the standard deviation of the scores was higher in the experimental group than the control group. While the overall scores increased, the higher standard deviation shows that students in this experiment responded to PBL at varying levels.

Retention of Material

While most studies have shown an increased achievement on assessments for students who learn through PBL, another effect of this type of learning is retention of material learned over time. Wirkala and Kuhn (2011) sought to investigate the effects of PBL in comparison to lecture/discussion on student retention. In order to do this, they investigated the effects of PBL in three sixth-grade social studies classes in an alternative urban public middle school. The student body of the school was very diverse ethnically, socioeconomically, and academically. There was an approximately equal distribution of African American, Hispanic and Caucasian ethnicities, and 60% of students qualified for free and reduced lunches. Academically, the students were diverse but all students in the study, based on standardized tests, were at or above grade level and no students receive special education services at the school.

Within the study, participants were instructed on two completely new topics (group think, learning and memory) in order to minimize the effect of previous knowledge on the results. Each topic was covered over three 40 minute class sessions over the course of one and a half weeks. The first topic was experienced at the end of sixth grade and the second was done at the beginning of seventh grade which allowed the researchers to investigate the effects on retention for the students. Each class in the study experienced a different format of learning for each topic. The potential groups were PBL-team, PBL-individual and lecture/discussion. To assess student understanding researchers used a comprehension assessment where students were asked to explain concepts directly as well as an application assessment where students were given a new scenario and were asked to apply the concepts. The results of the study showed that long-term retention was superior in those students who experienced PBL in comparison to those who were in the lecture/discussion group. While PBL instruction resulted in superior comprehension and application of new material, the research showed it was not impacted by individual vs team.

The results of Wirkala and Kuhn (2011) are in agreement with the results of Dods (1997). Dods (1997) found that the content encountered in a PBL environment showed significantly greater retention to the content encountered in a traditional lecture environment. More so, it was found that content in later evaluation that received higher scores was more likely to have been learned in a PBL experience than a lecture experience. The results of both Wirkala and Kuhn (2011) and Dods (1997) were also seen in a study by Wong and Day (2009). Within this study, it was found that although PBL doesn't always increase immediate achievement, long term retention is significantly increased in a PBL setting.

Wong and Day (2009) compared problem based learning and lecture-based learning (LBL) in a Hong Kong secondary science class. The study sought to "examine whether younger and less able students than those in medical schools can benefit significantly from the application of the PBL model" (p. 627). The researchers focused on both the immediate impact of LBL in comparison to PBL as well as the longer term effects of both learning methods. The participants of the study were from two different classes, ages 12-13 and there were approximately the same number of boys and girls. According to Hong Kong's three band selection system, all students were defined as middle ability level, with an attainment test score of only four percent difference between the groups. The classes have never experienced PBL prior to the study, but they are new to the school setting as they just moved from primary school to secondary school. It is less likely that the student perceptions and attitudes about a new method of learning were biased because this was their first experience in the new setting. The study covered two topics: human reproduction (which holds high intrinsic motivation for students) and density (which is historically of low interest to students).

One class was taught PBL, and the other class was taught LBL. Within the PBL class, the model used followed a three phase pattern. The pattern began with a problem introduction where groups of students analyze the problem with guidance but no content instruction. The students then conducted research and created products to present the solution to the problem. Finally, the groups reported their findings to the class and the teacher. The LBL group experienced lecture-based teaching which included interaction between students and teacher as well as questions to bring out prior knowledge. According to the researchers, "this style tends to discourage student-student interactions in favor of a conventional orderly class-teaching environment" (p. 630). Students took a pre-test before the new learning and two post-tests after the learning, one immediately after the completion of the lessons and one two months after the learning. All of the tests administered examined students ability to recall facts and to apply their knowledge.

The pre-test and immediate post-test mean scores were quite similar between the LBL group and the PBL group, indicating no significant difference between the two learning methods. The researchers concluded that a lack of significant difference indicates PBL is at least as effect as LBL methods. The results were then broken down into the two topics covered, and the results for density were significantly better for students in the PBL group when compared to the LBL group. Density was the second topic covered, so improved results for this topic could be seen as a result of experience in the new setting. The results of the delayed post-test showed significantly better scores for the PBL group when compared to the students who experienced LBL. These better scores were seen in nearly all categories of questions and in the overall scores of students. These results indicate that students who learn through PBL are better able to recall what they have learned in later tests.

Wong and Day (2009) concluded that retention is higher for students who experience PBL compared to students who don't, even if immediate achievement is not increased. This was also revealed through a study with medical school students. Purshanazari, Roohbakhsh, Khazaei and Tajadini (2013) conducted a study with thirty nine medical students in respiratory physiology enrolled in Medical School of Kerman University of Medical Sciences in Kerman, Iran in order to evaluate the impact of PBL on students short and long-term retention when compared to the traditional learning method. The study began with a pre-test intended to measure basic understanding of respiratory physiology. After the pre-test the students were randomly assigned into three groups, one PBL and two traditional learning groups, each containing 13 students. The PBL group was given a series of questions to research and then they discussed it with the class on the next class period. A tutor was available to correct mistakes and to aid in drawing conclusions about the topic.

The results of the study were measured by a test that all the students took at the end of the semester. This test was repeated one year and four years later with the same students without a notice before hand. The pre-test results revealed no significant difference between the groups before instruction. The final exam results initially indicated no significant difference between the groups, but the scores of the test after one year and four years showed significantly higher scores for students who experienced PBL than those who didn't. The difference between the groups were significant after one year with a p value of < 0.05, but were even more significant with a p-value of < 0.01 after four years had passed. A strength of this study is that retention can be measured over a longer period of time within a medical school than in a secondary school setting.

Ability to Apply Learning to New Situations

Wirkala and Kuhn (2011) sought to assess students ability to explain concepts directly, as well as students ability to apply concepts to a new scenario. Through their study, students who learned in a PBL setting were able to apply the material to new situations better than students who learned in a lecture/discussion setting. Similar results were seen in a study by Capon and Kuhn (2004) conducted in a business school. The study focused more on the long term, rather than the immediate mastery of new concepts. Participants included two classes of 60+ students enrolled in and Executive MBA program. Both classes were taught by a senior professor with experience in both lecture/discussion teaching and PBL. The students were also familiar with both types of learning. Within this study, each class experienced both types of learning with a different topic.

The lessons for each type of learning took place over one day within one single two hours and 45 minute class session. To assess student learning, the researchers used the course final which was administered twelve weeks after the lessons. In order to allow students to access and apply both topics covered in the study, the question on the final was an open-ended essay based on a general prompt. The students also took an un-announced quiz six weeks after instruction. The quiz together with the final exam allowed for comparison between processing of the concepts at six weeks and twelve weeks.

The use of a coding system were used to compare the answers on the quiz between students. The system was leveled from lowest understanding to highest understanding. The quiz results (six weeks after instruction) indicated that the lecture/discussion group had an as good or better representation of the concepts at this point. The final course assessment results (twelve weeks after instruction) showed a superiority for the PBL group compared to the lecture/discussion group. Ultimately, the course assessment results were superior for PBL students in their ability to go beyond the simple definition of a concept and really expound upon its meaning and uses. "Students who experienced problem-based instruction more often were able to integrate newly acquired concepts with existing knowledge structures that had been activated. In more everyday language, they demonstrated understanding" (p. 74). These results show that PBL did not result in superior acquisition of new concepts, but greater understanding and ability to integrate the new concepts with prior knowledge. One limitation to this study is that the students were highly motivated to learn because their employers paid for the course.

The ability to apply learning to new situations is also a result seen in the study by Tarhan, Ayar-Kayali, Urek and Acar (2008). In their study, "the purpose of the research was to examine effectiveness of PBL on 9th grade students' understanding the subject of intermolecular forces: dipole-dipole forces, London dispersion forces and hydrogen bonding" (p. 287). To explore this, the participants included 78 ninth grade students from one high school in Izmir, Turkey. The students were put into two groups, a control group that was taught through the traditional approach with 38 students, and the experimental group that was taught trough PBL with 40 students. The groups were formed by the scores on the pre-test administered prior to the learning, and their grades from the previous two years of science. The same chemistry teacher, who had experience in active learning and PBL, taught both groups through the same number of total lessons.

Prior to instruction, students took a pre-test with four open-ended and eight multiple-choice questions. The concepts covered on the pre-test are fundamental to intermolecular forces and included: periodic table, electron configurations, Lewis structure, octet rule, electronegativity and ionic and covalent bonding. Following the pre-test, students in the experimental group were assigned to groups based on pre-test scores, science grades and social abilities determined by the teacher. An orientation to PBL was delivered, and then students were introduced to the problem. After the problem was introduced the students developed research questions with some guidance from the teacher. The students then collected information about the research questions outside of class with the use of library materials and internet resources. The next class period allowed time for the groups to discuss their findings and answer the questions. The class period ended with a fifteen minute period of explanation where the teacher explained the concepts to the students. The students within the control group were instructed on the same concepts, but with a teacher-centered traditional format. Within this class, the teacher lectured while students listened and took notes.

Immediately after completing the lessons each group took a post-test with 6 open-ended questions and six multiple-choice questions to measure their understanding of intermolecular forces. The tests were both validated by a group of teachers and piloted with 150 ninth grade students to determine reliability. There was also a voluntary and confidential questionnaire consisting of three opened ended questions about the teacher's performance, quality of the PBL problem and group functioning that collected data regarding the beliefs of students' about PBL. The tests were graded and scores were agreed upon by the researchers, two expert tutors and the teacher. The results of the pre-test scores showed a mean of 73.7 for the experimental group and a mean of 70.5 for the control group. The results of the post-test scores showed statistically significantly higher scores for the experimental group with a mean of 81.8 compared to the mean of the control group of 62.4. Specifically, the PBL students' answers to the open-ended questions on the post-test showed that they were superior in using the scientific ideas in situations that required critical thinking. The students in the control group showed multiple alternate understandings of the topics, while the students in the experimental group did not.

Increase in 21st Century Skills

There is assessment evidence that shows student learning is positively impacted by PBL, but there are more benefits to this method including the increase in 21st century skills. "PBL has a wide range of benefits such as being student-centered; helping students to develop miscellaneous points of view; performing deep, active and meaningful learning; and developing problem solving, researching, creative and critical thinking skills" (Celik et al., 2011, p. 657). One study conducted by Wan Husin et al. (2016), concluded a significant difference in certain 21st century skills for students who encountered PBL. The investigators focused on the 21st century skills of digital age literacy, inventive thinking, effective communication, high productivity and spiritual values. The participants of the study included 125 secondary school students, from mainly rural areas, aged 13-14.

The students in the program experienced project focused PBL that covered multi-disciplinary activities. The study covered four units of content including energy, urban infrastructure, transportation and wireless communication. Students completed an expert verified questionnaire before and after the program that measured their perception of their 21st century skills. The results showed an overall increase in the mean score for 21st century skills, with a significant increase in digital age literacy and high productivity. There was not a significant difference in inventive thinking and effective communication. One strength of this study is that the students served as their own control with a pre-test post-test format. One weakness of this study is that the growth of the skills was measured by the perceptions of the students.

Digital age literacy and high productivity are increased through PBL, but there are other skills necessary in the 21st century. A study of high school seniors sought to compare the effects of a PBL approach to teaching compared to a conventional teaching (CT) approach in a mathematics classroom (Tarmizi, Tarmizi, Loginin, & Mokhtar, 2010). Over six weeks the treatment group was taught using the PBL strategy, in which students were given a problem prior to any instruction on the topic, and the control group was taught using conventional teaching. The students in this study in the treatment group solved the problem based on the notes prepared by the teacher and the examples and explanations from the textbook. After solving the problem, as a group, the students presented the solution to the class. After group presentations, the teacher would reinforce the concept by explaining it again. The students in the control group were taught through teacher introduction of the concept, teacher demonstration of examples, and finally practice with similar questions to the examples demonstrated by teacher.

The goal was to examine both cognitive and affective attributes of students. Cognitive attributes studied included the number of errors, mental effort and mathematical performance. Affective attributes studied included teamwork, mathematical communication and mental effort. To measure mathematics performance the students in both groups took a post-test given by the teacher. Mental effort was measured by a nine-point symmetrical category scale in which a numerical value was assigned based on the perceived mental effort. Students were the ones who assigned a numerical value to their own mental effort after each question. Throughout the lesson, the researcher (instructor) assessed students on their affective attributes based on the rubric provided. The attributes were measured on a scale of five (strongly agree) to one (strongly disagree).

The results of the study showed that although the mean scores for the PBL group were higher than the CT group in regards to mathematical performance, the results were not statistically significant. Mathematical communication, teamwork, working with others and attitude in group were all higher for the students in the PBL group than the CT group. "In conclusion, the PBL group seemed to display better mathematical communication skills and showed stronger teamwork as compared to the control group" (p. 4686). This study showed that although the mathematical achievement is not always statistically significantly higher, students who experience a PBL setting are able to increase skills such as communication and teamwork.

Schools allow students to learn a variety of different skills, and an increase in positive behavior is something that will benefit students beyond the walls of a school. Gordon, Rogers, Comfort, Gavula and McGee (2001) found that students who were exposed to PBL two percent of the time showed a positive increase of behavior ratings. This study focused on the impact of PBL on behaviors and performances of minority middle school students. Based in North Philadelphia, Stoddart-Fleisher Middle School is a sixth to eight grade public school. The population is 90% African American and ten percent Hispanic with 96% of students living below the poverty line. The study had a control group who was taught in the traditional manner where the curriculum stayed the same, and an experimental group who participated in PBL. The groups were created by two classes from each of the three grade levels. To implement PBL in the classrooms, the school had thirty plus staff members including the school nurse, counselor, secretaries and security staff trained as facilitators.

Throughout the duration of the study, only two percent of the curriculum schedule was represented by PBL activities for the experimental group. The students in the PBL group typically met for the first two periods on Tuesday, Wednesday and Thursday. The first day allowed the students to deconstruct the problem and develop different learning issues to investigate. The learning issues were distributed among students to be responsible for researching. The next two class periods were for research where students used the library and internet sources to learn more about their particular learning issues. The following class periods were used for students to share information they discovered while researching, and to apply their findings to solve the problem. The final session consisted of the construction of concept maps to reinforce learning, and connect findings. The students in the experimental group were taught PBL in all of sixth, seventh and eighth grades. The students perceptions of PBL were measured through a survey based on a five-point scale. The report cards of both groups were also used to analyze the impact of PBL.

The results of the study were positive, especially in regard to the behaviors of students in the control group. The staff and administrators commented on the impact of PBL on the behavior of students prior to the analysis of behavior ratings. Quantitatively, the students who started PBL in sixth grade showed significantly better behavior ratings in the following years. The researchers concluded, “when used as an enrichment activity for just two percent of the curriculum, problem-based learning improved behavior and increased science performance of low-income minority middle school students” (p. 173).

The increase of 21st century skills through PBL was also seen in a study conducted by Sungur, Tekkaya and Geban (2006) with 60 students in two tenth grade biology classes. The study focused on the question, "are there differences in the effectiveness of PBL and traditionally-designed biology instruction on tenth-grade students' academic achievement and performance skills in a unit on the human excretory system?" (p. 156). To investigate that question, the 60 students, including 39 boys and 22 girls, from two classes were divided into an experimental group and a control group. The previous grades of the students were compared and the experimental group scored a 4.6 and the control group scored a 4.7 both out of five. The four-week long experiment allowed each group to be instructed for four 40-minute class periods.

The students in the control group were taught with a traditionally-designed biology instruction that consisted of the teacher explaining the information, students reading of the textbook, student discussion of the concepts after instruction and, practice on a worksheet. The experimental group was broken down into smaller heterogeneous groups of six students. The students and the teacher were then trained in PBL, which consisted of the students working in their group, within their particular given role and responsibility, on ill-structured problems. Individually, each student was also responsible for conducting their own study. Each lesson concluded with evaluation of the students effort and suggestions for future improvement. Students were expected to spend time outside of class to study learning issues. The teachers role during the sessions was to create a positive environment, ensure student control in the class, provide open-ended very general questions as guidance when needed and encourage critical thinking of the students.

To measure the results the researchers collected data through a pre/post Human Excretory System Achievement Test (HESAT) and a PBL feedback form. The HESAT, created by the researchers, included 25 multiple choice questions and one essay question. The goal was to measure students' academic achievement as well as their skills. The items on the test were examined by experts as well as by teachers and the multiple-choice part of the test had a reliability of 0.70. The PBL feedback form had two parts, the first had 14 items that students rated on a five-point scale, and the second was seven open-ended questions that allowed students to share opinions of PBL. The student tests were scored by two independent raters and similarities and differences of the scores were discussed until consensus was reached. The essay question was rated based on performance skills of identifying, exploring, prioritizing and envisioning.

The researchers in this study emphasized the skills necessary for the world beyond the classroom, and this included the performance skills that were assessed with the essay question. Prior to treatment students took a pre-test that revealed there was no scientifically significant difference between the control and the experimental group. The post-test results were analyzed, and they revealed that there was a similar level of simple fact recall in both the experimental group and the control group, with a mean of 9.6 and 9.7. The experimental group was found to apply knowledge and integrate learning at a higher level. Academic achievement and performance skills were both analyzed and it was found that the experimental students achieved better at a scientifically significant level than the students in the control group. "Students' responses in the essay revealed that students in the experimental group could better use relevant information in addressing the problems, interpret the information and use the principles to judge objectively" (p. 157). This study revealed that students who experienced a PBL setting gained skills in identifying, exploring, prioritizing and envisioning, which are all skills used in the 21st century world.

Gender Differences in STEM Field Interests

One area of research involving PBL that reveals differing results is that of gender differences in mathematics. This is an important area of research because men continue to outnumber women in both STEM graduate level degrees and STEM areas of professional work (Schettino, 2013). One set of researchers sought to investigate the self-efficacy of males and females and whether or not PBL would have an impact on what students believe about themselves (Brown et al., 2003). Self-efficacy is significant in the area of gender differences in STEM fields because, "academic self-efficacy can influence students' desire to engage in and maintain interest in pursuing academic goals" (p. 259). Self-efficacy does not measure ability or achievement, but a person's perceived potential for success.

With a virtually equal number of males and females, 234 students from the states of Connecticut and Massachusetts participated in a simulation of international studies. Six to eight weeks prior to the simulation, students were assigned a country to represent in the simulation. After being told to "stay in character" for their particular country, they were given five focus areas (human rights, global environment, conflict and cooperation, international economics, and world health). In order to stay in character for their country, they learned about the values and customs before the simulation. Sixteen different classes representing 16 countries participated in the five week long simulation. Participation in the form of online meetings, emails, research, or preparing documents, was done each school day. Students could also participate outside of class with their own computers at home. The students from each country remained anonymous, including gender and grade. Within the countries there were groups formed that were all-girls, all-boys, or mixed gender. The groups were then assigned by the teacher a specific issue area to represent in the simulation.

In order to collect data for the study, students were given assessments that measured demographic information, self-efficacy information, “and knowledge, attitudes and behaviors (KABs) regarding international politics, using computers, working in groups, and problem-solving” (p. 263). The pre-test and post-test scores had reliabilities calculated in order to ensure stability. The Academic Self-Efficacy Scale was taken by each student, and factors of effort, learning preferences, and social comparison were labeled. Those underwent a reliability estimate and scores of 0.87, 0.88, and 0.66 were found. Therefore, results in regard to social comparison are not reliable. The results of this study indicated that females did not grow in the self-efficacy after the PBL, and there is still a discrepancy between males and females in regard to self-efficacy. “The analysis did indicate a statistically significant main effect for gender, with males scoring higher than females in both the pre and post-test, but not significant gains after the simulation” (p. 267).

Another way to describe a student’s self-efficacy is in their confidence and attitudes towards learning a particular subject area. Schettino (2013) reported on a study that involved the journey of five adolescent girls studying secondary mathematics through a PBL approach and their attitudes towards the STEM fields. The research focused on the relationship between their attitude towards math and their experience of learning before and after a form of PBL, as well as how they individually described their experience. The students were taught mathematics in a relational problem-based setting, which is defined as, “an approach to curriculum pedagogy where student learning and content material are (co)-constructed by students and teachers through mostly contextually-based problems in a discussion-based classroom where student voice, experience, and prior knowledge are valued in a non-hierarchical environment utilizing relational pedagogy” (p. 468). The relational piece is in connection to the feminist relation. The researcher noted that many aspects of the feminist relation are included naturally in PBL including discourse and opportunities for open-ended questioning.

Data for the study was collected over six months through student interviews, classroom observations, teacher interviews and student journals. Through analysis of the data, it was concluded that confidence in all of the girls, with the exception of one who previously claimed high confidence in her own mathematical ability, grew throughout the year. The empowerment seemed to change as a result of looking at mathematics through a lens of multiple perspectives, valued inquiry and it’s connecting new knowledge to prior knowledge. The researcher concluded that the experience in relational PBL allowed students to gain confidence and empowerment as a results of, “the purposeful dissolution of any authoritarian hierarchy with deliberate discourse moves to improve equity and send the message of valuing risk-taking and all ideas will create a sense of shared authority” (p. 471).

A study in 2015 stated that although the gender gap is narrowing in mathematics, “gender differences in mathematics achievement and ability has remained a source of concern as scientists seek to address the under-representation of women at the highest levels of mathematics, physical sciences and engineering" (Ajai, & Imoko, 2015, p. 45). This factor motivated Ajai and Imoko (2015) to measure differences in mathematics achievement and retention based on gender in a study in Nigeria. The researchers looked at the differences in achievement of male and female students taught using PBL. The subjects, selected through multistage sampling, were from ten secondary schools across the Benue State of Nigeria, totaling 261 male and 167 female senior students.

The study utilized a pre-test and post-test quasi-experimental design. PBL was used to teach the students algebra. Data was collected through the algebra Achievement Test which was created by the researcher and validated by experts in mathematics and science education. The assessment included 25 multiple choice questions and seven essay items. The teachers all had at least three years of experience and were trained to facilitate PBL. All students were taught the lessons for four weeks. The results revealed no significant difference between male and female students taught using PBL in regard to their mean scores. "This indicates that there is no significant difference between the retention mean score of male and female students taught algebra using PBL" (p. 48). The researchers concluded through this study that male and female students are on the same level when they are able to compete, work together and learn from one another about the mathematics. While this study did indicate a decrease in gender gap in mathematics as a result in PBL, it is a case study so further research is needed to study the findings at a greater depth. The study also examined gender differences, but was not complete in the examination as it did not include things such as classroom cultures, teacher attitudes, and parental attitudes.

Student Satisfaction

A final effect of PBL that should be considered is student satisfaction with the method of learning. The perceptions of students are mixed, with some viewing PBL as a tool that is beneficial to their learning and fun, but others who struggle with the new form of learning. In the study conducted by Dods (1997), the students completed a course evaluation after the implementation of PBL, and the results indicated that the course was interesting and enjoyable. Students reported it was relevant to their interests, that they worked in a collaborative manner, out-of-class preparation was less than a typical course, but they believed they encountered less content than if it were purely lecture. The study conducted by Gordon et al. (2001) with minority middle school students revealed that students had a positive experience with PBL. Through a survey measured on a five-point scale, the students rated "I like being responsible for what I learn", "I would like to use PBL next year" and "I like PBL" with mean scores of 4.3, 4.2, and 4.2 respectively.

The ninth grade students in Tarhan et al. (2008)'s study were a little more apprehensive about PBL and the impact it had on their learning. Students volunteered to take a confidential survey at the end of the study that consisted of three open ended questions about teacher's performance, quality of the PBL problem and group functioning. Generally, the responses revealed a basic understanding of PBL, but a lack of readiness for the change. Students felt they needed more time to gain experience before fully learning through the new approach. The researchers stated, "75% of them did not want to be responsible of their own learning and indicated that they needed teachers support" (Tarhan et al., 2008, p. 298). This belief of needing teacher support was revealed through their answer to the quality of problems, with the belief that problems should include leading questions. The students also emphasized the importance of the teacher visiting their groups throughout the process.

While Tarhan et al. (2008) revealed an apprehension from students to take responsibility for their own learning, Akti and Duruhan (2019) discovered students struggled with the cooperative component of PBL. Although students generally were satisfied with their group friends, some expressed negative opinions of the PBL approach including intra-group disagreements, all members of the group not participating in the activities performed and some of the students working individually within the group. The results of the study by Sungur et al. (2006) that utilized a student survey to analyze student perceptions and opinions of PBL showed that students enjoyed the collaborative aspect. The student survey revealed positive attitudes about PBL from the students, focusing mostly on working together, gaining skills to access information and decide what to use, and seeing practical applications of the learning first hand. Although the students communicated a generally positive attitude about the learning method, students did communicate that adapting to the new roles of PBL is more challenging. "They wanted more teacher participation and guidance. They suggested that the teacher should provide answers to their questions and that brief lectures could be integrated into the PBL sessions" (p. 158).

Goodnough and Cashion (2006) conducted a study specifically focused on implementation of PBL with heavy input from students in regards to their beliefs about the approach. The researchers sought to explore the complexities of PBL and to study its feasibility for use in a high school science classroom. The study included 26 12th grade students with above average academic ability as described by the teacher, all enrolled in a one semester Biology course. The study was conducted over a the course of a year under an action-based inquiry method that consisted of a high school teacher and two university researchers. To collect data the researchers used participant observation, documents and semi-structured interviews. The participant observations were by the three researchers conducted through multiple meetings throughout the year of research that allowed for reflection, developing insights and analyzing data. The documents included things created in the planning stages of implementation as well as student work. The students were interviewed at the end of the experiment.

The results of the research focused on student perceptions throughout the process of implementation. Students believed they gained skills like negotiation, research skills and presentation skills as a result of PBL. The students shared multiple reasons for liking the PBL experience including variety in learning experiences and the opportunity to engage in active learning.

Goodnough and Cashion (2006) showed that students enjoyed the experience of PBL, and Ceasar et al. (2016) also discovered students enjoyed PBL as witnessed through an increase in motivation and engagement of students. The studied focused on measuring the effectiveness of a PBL approach in the promotion of a positive learning environment for students in a geography classroom. The researchers also looked at the student perceptions of PBL specifically in their motivation and interest levels. The participants included were 14 to 16 years old in two different geography classes totaling 60 students. The students had mixed abilities, skills and motivations. The study followed an action-research format with two cycles of research, one during the investigation portion of research and one during a group of four to five students investigating a particular earthquake event. Prior to the first cycle a pre-test activity was conducted. The students were then given a month for investigation lessons where they recalled ideas and knowledge learned before and shared new information they had learning during their own individual research. The students were then given a post-test at the conclusion of the cycle. During the second cycle the focus was on the development of students' content knowledge.

Data collected during the study consisted of individual test work samples, student interviews and observations. The results of the student tests show that content knowledge increased from the pre-test to the post-test. The results also indicated an increase in engagement demonstrated by students who participated in the classroom not because they had to or to please the teacher, but because they actually valued the activity. These results were also seen in the increase of interaction and discussion between students. The observations also revealed an overall increase in student motivation. While overall motivation and engagement were increased, observations revealed that some students were less active in participation and did not work with others. These things both affected the final group presentations and the learning experienced by group members. The researchers stated, "It is vitally important for teachers to regularly remind students on the context of the exercise and its content matter to ensure students select and handle appropriate materials" (p. 59).

How Has Problem-Based Learning Been Implemented in the Classroom?

Teachers should consider a few things before implementing PBL into their own classroom. First, it is important to consider the role of both the teacher and the students, as it is a shift from the traditional method. Next, it is important to discuss how a teacher is to gain the skills necessary for implementation, which comes in the form of workshops and teaching training programs. Finally, it may be helpful to reflect on specific examples of implementation in the classroom and the variations that have been tried by other teachers. Below is a review of research regarding the roles of the teacher and students, training methods and examples of implementation of PBL in the classroom.

Role of the Teacher and Student

When considering a new method of teaching, it must be viewed with the impact on students and teachers in mind. Goodnough and Cashion (2006) spent a semester in a biology classroom investigating the implementation of PBL and they concluded that the role of both the students and the teacher must change. "PBL necessitates new roles for students, as well as new roles for teacher. Hence, students need to be prepared to participate in a new way of learning and practitioners need to give careful consideration to student abilities and skills that need to be engaged before and during PBL implementation" (Goodnough, & Cashion, 2006, p. 292). The first thing to notice is that the teacher can be considered an education director according to Celik et al. (2011). The teacher acts as a director to the students as they do the thinking, the investigating and the discussing. "The instructor no longer lectures. Instead, when the instructor integrates PBL into the course, students are empowered to take a responsible role in their learning. The instructor is not the authoritative source of information and knowledge" (Ajai, & Imoko, 2015, p. 47). This new role as facilitator rather than information transferring can be described in more detail.

In a study conducted in several classrooms that were already implementing PBL, Yukhymenko et al. (2014) explored the practices teachers implemented in order to function in the new method of teaching. The goal of the study was to both investigate the role of the teacher as well as responses of students in a classroom with a PBL environment. Four middle school classes from the state of Connecticut that were participating in GlobalEd 2 in the fall of 2010 were involved in the study. The GlobalEd 2 is an online simulation based on real-world international issues that utilizes a PBL approach with phases including preparation, simulation and debriefing. The learning environment of GlobalEd 2 is different from traditional learning approaches because it is centered on students. Students work with others in small groups, make decisions together and seek solutions to real-world issues. The teachers act as facilitators by being available for support, providing resources, and directing students' learning. The teachers who participate in the program are required to attend a PBL workshop in the summer. The workshop discusses classroom culture components necessary to PBL, the rules of GlobalEd 2, and allows teachers to participate in a mini PBL simulation in order to see the theory in practice before teaching it in their own classroom.

To analyze data in this study, the researchers utilized a hybrid of inductive and deductive thematic analysis approaches. Deductive analysis tests the data against current theories, assumptions and hypothesis, while inductive analysis allows the researchers to derive the theory as it is pulled out of the data. "The hybrid approach of inductive and deductive thematic analyses is a thematic coding that allows a balance of inductive coding (derived from the raw data) and deductive coding (derived from theoretical framework)" (p. 98). To gather the data, researchers observed while taking video of the classes for one semester. The observations, that took place during the interactive phase of GlobalEd 2, occurred in November, after two months of PBL in the classroom. Both the transcripts of the videos and the field notes of the observers were analyzed.

The results showed that the practices of teachers began with distributing resources and materials to the students while encouraging them along in the problem. The teachers also spent minimal time on giving directions to students and lecturing about the content. "Teacher does not serve as a dispenser of information, but rather as a coach or a tutor to the students, by leading students and proposing ideas" (p. 103). The teachers released control of the lesson and allowed students to make their own decisions regarding what resources to use and what investigative avenues to take. During a lesson the teachers activated prior knowledge and helped students make connections to apply that to the problem they are solving. The teacher also asked timely questions that lead students to the next step. The teacher monitored student progress, provided direction if necessary to each group as they worked through the problem. One last thing the researchers found was that teachers ensured the classroom environment was positive in order to warrant student success.

The students worked in small groups with equal participation of each member according to their given role in the group. Students managed resources on their own, and worked together not only in their immediate group, but with other groups in the class as well. The students were responsible for applying their thinking to the problem they were solving, and discussing the solutions with others as well as sharing resources. As summarized, "In PBL classrooms, students feel responsible for what is happening during PBL and for how to find a solution to the problems. They are self-directed, often independent, and are willing to help all students in their small group" (Yukhymenko et al., 2014, p. 103). While the traditional teaching methods typically encourage the teacher to maintain the role of "imparting the information deemed necessary to fully understand the topic under consideration," (Dods, 1997, p. 424) while students maintain a more inactive role, PBL requires completely new roles for both the teacher and the students.

Impact of Training on Implementation

The next thing a teacher must consider when implementing PBL is how the new skills required to teach such a different method will be learned. In a study by Hendrix et al. (2002), the impact of workshops on the understanding of PBL was investigated. The study was conducted around The Healthy Challenges Project (HCP) that trained teachers in PBL by providing incentives and funding for educational materials to encourage teacher participation. The teachers selected were found by inviting 1,500 principals to distribute brochures about the HCP to interested teachers, and 97 teachers responded and attended the training workshops. Of the 97 teachers, 14 taught science, 11 taught physical science, seven taught math, four taught social studies, four taught English/Reading, three taught health careers, two taught life skills with the remaining 52 primarily teaching health. The teachers involved in the study were compared to other teachers who were selected by grade and county.

The focus of the HCP was on training teachers to use the PBL model to teach health through two-day workshops. Workshop participants learned about PBL, observed student demonstration groups, solved PBL cases, and designed health cases about tobacco use. They received a resource kit with videos, posters, brochures, and pamphlets. All the content related to the years health focus topic of tobacco use. The most impactful part of the workshop for teachers was the live demonstration where students were invited to participate in a PBL lesson while the teachers at the workshop quietly observed. Within the workshop they were also broken into groups of teachers who taught the same grade and given time to create their own PBL lessons to be used with their students. Pre and post-test assessments measured the teachers knowledge growth as well as attitudes about both PBL and the HCP.

The data of this study was collected through the completion of pre and post-test assessments by the teachers involved in the study. The full participation rate of the study was 55% with only 53% of the teachers returning both sets of assessments. The first result seen from the assessments was that the workshops successfully generated enthusiasm about PBL implementation, as well as increased teacher understanding of the method. The teachers did report spending more time creating PBL lessons, but responses reveal that the benefits outweighed the additional preparation time for teachers. This is concluded based on the positive feelings about PBL from the teachers. The teachers' reflection on the workshop indicated that the most impactful part of the time was the hands-on demonstration to the approach. They suggested that witnessing PBL implementation with a group of students, experience in the use of the technique and time to design their own PBL lessons is important for teachers.

While Hendirx et al. (2002) revealed the power of workshops to impact teacher implementation of PBL in the classroom, Pecore (2013) investigated how a teacher's beliefs truly align with the principles of PBL after participating in a workshop. The study involved four secondary science teachers with at least three years of experience. The teachers had taught at least one year after participating in a PBL workshop. The selection of the teachers was based on both experience and participation in a workshop as well as willingness to participate in the study and approval of their school system. The workshop was a one-week long summer PBL professional development attended by multiple teachers from the same schools with signed principal support. The teachers spent time observing, experiencing and writing PBL lessons. One activity included in the training was a veteran PBL teacher who delivered a lesson to high school students while the teachers attending the training observed.

After the workshop, a case study approach guided the research. The case study encompassed a two week window where participants taught the PBL unit on the classifications of kingdoms. To collect data, the researchers used a Constructivist Learning Environment Questions (CLEQ), observed teachers using the Constructivist Classroom Observation Form (CCOF), and conducted semi-structured interviews with the teachers. To avoid errors and biases, a case study protocol and database was utilized by the researcher to triangulate data. The data was coded and the researchers developed a profile of each teacher's experience of the PBL lesson implementation.

The results of the research indicated that while the teachers expressed certain beliefs about constructivism and attempted to apply those beliefs in the classroom through PBL, the two experienced teachers self-reported a higher degree of alignment than the two teachers with less experience. The participants all reported beliefs within a high range, but revealed in practice that the principles were more represented in the teachers with more experience. Ultimately, this study revealed that a change in surface level instructional beliefs may not change the instruction because teachers modify the features to fit their current instructional practices.

One more potential area to develop skills in PBL is through teacher training programs prior to earning a degree. This avenue was explored by Wynn and Okie (2017) with a group of preservice teachers (PSTs) enrolled in a social studies methods block. The goal of the study was to change the secondary social studies methods course to focus on the preservice teachers gaining experience and practice with PBL. The study focused on factors that PSTs identified as affecting their implementation of PBL in the classroom. The participants included 12 students enrolled in the methods block that completed both the practicum and student teaching period of 16 weeks in a high school social studies classroom. Within the 12 participants, five were female and seven were male. The course consisted of an in class meeting for two hours and 45 minutes one day each week, as well as at least 75 hours of in classroom practicum. The practicum class began with a three week time period of introducing students to PBL so they could experience the method first hand.

A case study approach was used for this study to gain understanding of student perceptions. The researchers explained that a case study approach, rather than a quantitative approach allowed lived experiences of the participants to be taken into consideration within the results. The researchers identified consistencies and themes through a data source triangulation. To collect information of student perceptions the students completed a questionnaire and participated in a focus group that was audio recorded at both the end of their practicum in the fall and the end of student teaching in the spring. Both items determined the PSTs perceptions of their preparation to plan and teach PBL lessons, the total number of PBL lessons they did teach, a list of positives and challenges found through teaching PBL lessons, factors that either encouraged the use of

PBL in their classroom or discouraged it, and the extent they plan to use PBL in the future. After data was collected the information was analyzed and triangulated through coding.

The results can be categorized into perceptions after the completion of the practicum and after the completion of student teaching. First, at the end of the practicum, the students communicated that they began with a confidence to plan and implement PBL based on their experience in the methods class, but communicated they felt anxious about how students would receive the PBL lessons. The worry was mainly focused on unexpected issues that may arise. Of the 12 students, 11 taught a PBL lesson during their practicum and ten of the 11 expressed that their worries were lessened after having taught one PBL lesson which allowed them to gain more confidence. The students communicated that a few positive factors that impacted their decision to use PBL included student exam scores improved, students improved writing skills, higher engagement, less classroom management issues as well as an improvement in deliberative and cognitive skills. The students expressed factors that limited the desire to teach PBL including time to implement and plan, the demands of coverage, standardized testing and student lack of experience with the new method of learning. Interestingly, all 12 of the participants planned to teach multiple PBL lessons in the future student teaching setting.

Second, at the end of student teaching the participants ranked themselves higher in regard to their preparedness to teach PBL lessons, but ultimately their confidence did not change. Overall, the positive and negative factors of PBL remained the same, but ultimately all 12 of the PSTs planned to implement PBL in future classrooms. The researchers summarized their findings with two implications. First, it is important to model the PBL process to preservice teachers as all the participants in the study identified experiencing a PBL learning process as crucial when they decided to try it on their own. Second, it is important to understand the cognitive dynamics of PBL.

These studies above all share a common theme that shows a teacher's ability to implement PBL in the classroom is affected by training, more specifically first-hand experience with a new type of learning. It is clear that PBL is a teaching method that is counter to the type of teaching that has developed over years (Pecore, 2013). Thus, because of the challenges PBL poses for both teachers and students it is important to provide workshops and effective training for teachers. This training, "addresses necessary classroom culture components of reform-based science instruction" (Pecore, 2013, p. 8).

Examples of Implementation

With PBL, it is helpful for teachers to consider specific examples of implementation in a teacher's classroom. While PBL has a broad definition that teachers can reference, others with experience have added different tools and experiences to improve the lessons for both teachers and students. Below is a list of four studies that have implemented PBL from the initial stage to more experienced stages. The first implementation was in an undergraduate engineering program, and the research focused on initial implementation of PBL and areas of improvement for subsequent semesters. The next three studies focused on additional tools that can be included in the PBL instruction to potentially increase student achievement. The tools include concept cartoons, guided tutors and a blend of knowledge construction and PBL.

Initial Implementation. A study by Henry, Tawfik, Jonassen, Winholtz and Khanna (2012) sought to examine an initial implementation of PBL in order to identify areas of improvement to the curriculum to change prior to a planned second implementation. The qualitative case study compares the students' initial reactions to PBL after the first problem completed at the beginning of the semester to the reactions as they completed the last problem of the semester. The researchers were guided by the question, "What changes are needed in order to improve student experiences as they transition to a PBL curriculum?" (p. 45). The participants were 54 junior medical engineering students enrolled in the spring semester of engineering materials at large at Midwestern U.S. University. The group was very homogenous with only two female students, two non-white students and one student who fell outside the 19-21 age range.

For the PBL instruction, students were first given an ill-structured problem and in groups they attempted to reason through the problem. In this stage they identified what they knew and what they needed to learn as well as the ways they planned to learn. Second, the students participated in self-directed study where, individually, they collected and studied resources to prepare to report to the group. Next, the students shared the learning that occurred in the second phase with the group and revisited the problem they were given. After two weeks the students summarized and combined their learning. Two instructors were the facilitators for the ten groups of students. The instructors were experienced in teaching the course, and had experience implementing PBL in previous courses but never a PBL course entirely. The instructors received guidance in PBL by the researcher who had extensive experience.

In this experiment the problems diverged from the basic PBL model in that they provided a guide to students that included relevant concepts with chapters that covered those concepts and a worked out example of the first problem. Students in this study had challenges with the PBL so some lectures were utilized after students had worked with the problem to address student misconceptions and address issues of collaboration. To scaffold problem-solving in the first half of the modules the students completed a planning worksheet that included key information, learning issues and task assignment. To collect data, researchers, led by a tenured faculty member who had experience in PBL research as well as implementation, observed participants during the class time as well as conducted semi-structured interviews. The interviews took place with a sample of students as they completed their final problem module.

The interviews were analyzed by two coders and the results were put into themes. Quotes were extracted from the interviews when both coders agreed they would illustrate the themes. From the themes, it was evident that students struggled with the lack of connection of the classroom content to the exams. While the teachers did give lectures throughout the lessons, after student feedback it was concluded that it was not enough to satisfy the students perception of a need for lectures. One particular student shared, “I think we absolutely need some kind of lecture before the problems are given” (p. 52). Students expressed frustration with a sensed lack of guidance from the facilitators. The greater “culture shock” for students in the PBL classroom was shifting from a role of passive absorber to self-directed learners. Although one student shared “It was good because I felt like it was useful to be able to learn on your own and I felt like I got a lot of out the reading” (p. 54). This student’s group was able to learn where to look and what was most important. Collaborative learning was not seen in many groups, and the students shared that structure included on collaborative work would have been better. Collaboration between groups was seen to positively impact learning and lesson the workload. Students struggled with the beginning of the problem solving process and sought validation that they were "on the right path."

While discussing the results, the researchers noted that the students learned to manipulate the teachers into assuming the more familiar role as lecturer and this in turn hindered their PBL. The teachers thought the lectures would aid students in the process, but in reality they may have had a more negative affect on PBL implementation. Despite the universal desire for more lectures from students, the participants still reported that they enjoyed PBL more than typical lecture style teaching.

Students in engineering are formula driven, "meaning that students' tendency is to see mathematical equations as ends rather than means" (p. 44). This view of learning causes a challenge within a PBL setting, and students desire the teacher to lecture on the given content in order to learn the formulas. This study reveals things to add to lessons to aid students in the transition from traditional learning towards PBL. The authors discussed things to consider in future course implementation including course design, how will assessment align with the tasks of in class work, and the inclusion of a whole-class discussion for students to have an opportunity to have their questions answered at the end of each problem. They also concluded that problems used in the learning should have multiple potential solutions to promote discussion amongst students which promotes knowledge construction.

Concept cartoons. Balim, Inel-Ekici and Özcan (2016) conducted a study that focused on the impact of concept cartoons on the inquiry skills perceptions and levels and ability to relate knowledge with daily life on students in a PBL classroom. The workgroup involved in the study consisted of sixth grade students aged 13-14 from nine different schools and 27 different classes. The sample included a total of 553 students with 47.6% male and 52.4% female students. There were three groups in the study, experiment group one, a concept cartoon integrated problem solving group with 177 students, experiment group two, a problem based learning group with 187 students and the control group with 187 students.

The study utilized a non-equivalent pre-test/post-test control group with quasi-experimental design. The experiment group one was taught using PBL that used scenarios appropriate to the objectives as well as concept cartoons integrated with the scenarios. Students in this group were given cartoons that allowed them to find solutions to problems in terms of the views in the concept cartoons. Concept cartoons are defined as, "visual tools in which cartoon characters declare views about an event from daily life" (p. 273). Experiment group two was taught with PBL and modules of only scenarios. The control group was taught with the typical science and technology teaching program. The students in each group were instructed for a total of 16 hours. To measure the impact of the concept cartoons the researchers used a pre-test and a post-test with an inquiry learning skills perception scale (reliability score of 0.94) and knowledge-daily life relating open ended questions (expert valid).

The quantitative results revealed that the inquiry learning skills perceptions were significantly higher for the experimental groups. Both the groups who learned through

PBL had an impact on students' inquiry learning skill perceptions, but concept cartoons did not have a direct impact on those skills for students. In regard to relating knowledge with daily life, the study found that neither PBL or concept cartoon integrated PBL had an impact on students. "The concept cartoon is a supportive tool for increasing student inquisition but does not make a direct contribution on students' inquiry learning skill perceptions when used with problem based learning" (p. 278). In conclusion, concept cartoons did not help students to learn better in a PBL environment.

Guided tutors. Another tool that has been added to a PBL setting is directive tutors that are intended to go beyond the role of a typical tutor or facilitator in PBL to provide more guided assistance to students as they solve the problems. This tool was investigated in a study by Budé, Van, Imbos and Berger (2011) with a group of undergraduate students in their first-year of study at Maastricht University. The goal of the study was to determine the effects on student conceptual understanding of statistics of directive tutor guidance. The participants were paid to be a part of the study to avoid only motivated students interested in statistics from being in the study. There were 68 students in the guided condition group and 70 in the control group.

The use of tutors was included to provide scaffolding when students prior knowledge is lacking, which can prevent an active participation in PBL. The tutors in the study were instructed to go beyond the traditional role of a tutor in PBL that contributes subject matter infrequently, to ask frequent directive questions and remain constant in guiding the discussions for the students. The tutors were given a set of written questions that they could ask within the class period, and were instructed to actively direct the discussion, not to provide answers or explanations to the students. The tutors included in the study were all experienced in the subject area, and prior to the study they participated in a two hour training that prepared them for their role in the PBL. They met weekly throughout the course for discussion and additional support.

The goal of the study was an increase in conceptual understanding of the students. The researchers defined conceptual understanding as “shown when a person demonstrates coherent, error-free knowledge structures. In this view, conceptual understanding is related to the quality of the knowledge structures of an individual learner” (p. 310). This is in contrast to knowledge reproduction that simply requires students to recall a term or definition, or be able to use a skill without understanding when and why the skill is useful. In order to collect data on the conceptual understanding of students, students took a test that contained ten open-ended questions that involved statistical hypothesis testing. The questions specifically asked for connections and explanations of the related concepts. The test was graded with a detailed marking key with thesaurus created by four statisticians. Data was also collected from the final exam scores. To collect data, different samples of students were measured at the two time periods, during the course and directly after the course. 24 students were also given the open-ended questions six months after the course completion to measure the retention of conceptual understanding.

The results of this study revealed that the students who had guided tutors had better conceptual understanding as demonstrated by considerably better scores. The students in the control group did not demonstrate the level of conceptual understanding at the end of the course that the guided tutor group did in the middle of the course. The final exam scores revealed that students in the guided section scored higher than those in the control section. The results of the assessment taken six months after instruction revealed that long-term retention of students conceptual understanding was low. The students in the guided condition dropped in conceptual understanding even lower than the control condition during the course after six months. The results revealed that guided tutors can have positive impact on students immediate conceptual understanding of statistics in a PBL setting, but do not impact the retention of conceptual understanding.

KC-PBL. One concern about PBL is the lack of content knowledge that is developed with this method of learning. PBL implementation is a challenge in secondary settings because there is an emphasis on content learning as well as skill development. Results regarding PBLs effect on content knowledge are inconclusive. This lead researchers Yeo and Tan (2014) to investigate the use of an integrated approach to PBL that included knowledge construction. The study focused on knowledge creation (KC) which places an emphasis on both knowledge and practice. Knowledge building, expansive learning and the trialogical approach are all examples of KC. The goal of the study was to give insight on how a KC-oriented PBL approach can resolve a content learning and problem solving divide in the science classroom.

This study was conducted as a case study with a goal of transferability for readers to decide how the findings can be applied to their own situations. Conducted at a local high school functioning under the Integrated Programme (IP) that allowed students in grades 11 and 12 to forgo a national qualifying exam at the end of their tenth grade year in order to allow more time to develop creative and critical thinking and leadership skills. In order to be selected for this programme students take a rigorous qualifying test and interview. This particular study was with one physics teacher and her students as they investigated a problem related to the Law of Conservation of Energy.

Within the programme, the department designed THINK, a science learning approach modeled after PBL. THINK contains five stages: Trigger, Harness, Investigate, Network, and Know. These five stages fall within the context of a typical PBL classroom with a real world problem (T), questions of students (H), time to research the questions (I), working with other classmates and experts (N) and presenting their learning (K). The particular THINK cycle studied lasted three lessons at two hours each lesson. The design of this cycle focused on the KC form of knowledge building which key feature is constant progression of knowledge. The students were introduced to knowledge building prior to the lesson, and they also had experience with knowledge building from previous lessons. To collect data, the researchers used online and video data of the interactions between students. The video of the lessons focused on one group in particular as well as the teacher when she was talking to the class as a whole. The data that revealed students' development of scientific ideas was collected from the notes students posted to the Knowledge Constructor, an online tool utilized in the lesson. The researchers also conducted interviews with the teacher and five students in a group. The interview questions focused on students' background, mediating tools and mediating roles and rules.

This study revealed that with a KC-PBL approach students participated in the advancement of knowledge about a scientific theorem while engaging in problem solving. The THINK cycle contained two activities that were dependent on each other and focused on both problem solving and theory-building. "These findings suggest that KC can be a useful boundary object to overcome the content-process divide, which created a hybrid space for students to cross between the boundaries of content learning and problem solving" (p. 770). One thing in particular that allowed this to happen is the teacher included a question that required students to build a model for a rollercoaster path, so students were required to learn the content while arriving at a solution to the problem. Although this study is only a case study, meaning the results aren't generalizable, the detail allows the readers to determine the application of the findings regarding KC to their own practices.

What are the Challenges of Problem-Based Learning?

The next thing to consider in the implementation of PBL are the challenges or existing critics of this method of learning. Within the challenges there are the problems students face, as well as problems for teachers. Another thing to consider as challenges to PBL is the way learning is cumulative in this method of learning. Below is a description of the challenges and problems within a PBL environment as described by the various studies in this paper.

Challenges for Students

The biggest issue that students face in a PBL classroom setting is the shift from an old approach to learning to a new, unfamiliar approach. This creates a need for more time to become comfortable and familiar with such a new approach, especially with students who are more familiar with a teacher-centered approach to learning (Caesar et al., 2016). This transition from a teacher-centered approach to a PBL classroom requires students to shift their understanding of the roles of the teacher and the students in the classroom. In the student surveys collected in their study, Henry et al. (2012) discovered that students expressed a frustration with a sensed lack of guidance from the facilitators. The participants in this study experienced a culture shock as they shifted from a role of passive absorber to self-directed learners. The students showed that the transition from teacher-centered learning to PBL is challenging as they as students are asked to maintain an unfamiliar role, and uphold new responsibilities in the classroom.

Challenges for Teachers

Just as students are expected to make a shift in their role in the classroom, teachers must make a shift as well. Fatade et al. (2013) highlight that most teachers tend to be aware of problem solving and the positive impact it can have in the classroom, it is more of a challenge for teachers to understand how PBL is truly different than the traditional approach. “For those teachers who understand what problem-based approach entails, majority are neither sure how to implement this approach in their classrooms nor are they interested in even to try it” (Fatade et al., 2013, p. 34). The lack of interest and hesitation to implement PBL in the classroom stems from the need for significant changes if implementation were to take place. The changes called for include choosing a problem that aligns with the curriculum goals and learning outcomes, determining the degree of structure provided by the teacher, adopting the role of the facilitator and the time it takes to do a PBL approach as compared to simply telling students the information (Goodnough & Cashion, 2006).

Lastly, it is seen that even when teachers understand what is necessary to implement such a change in the classroom, there are outside forces that stand as challenges as well. Pecore (2013) followed four teachers and analyzed their ability to apply principles of PBL to their actual instruction in the classroom. According to the teachers, one area of concern was administrative support, one highlighted it as a must for successful PBL implementation. Other obstacles they faced were low student motivation, limited time for instruction, a struggle to establish a collaborative culture within the classroom and week questioning techniques.

Learning is Cumulative

Critics of PBL argue that the lack of prior knowledge may impact a student's ability to be successful. Students, "May lack schemas and differentiated knowledge structures needed to incorporate new information into existing knowledge structures" (Wirkala & Kuhn, 2011, p. 1158). If the structure of PBL is to build new knowledge on previous knowledge this could be a potential issue for students.

The cumulative nature of PBL is not only seen with prior knowledge, but is also seen within each phase of the learning. Yew et al. (2011) focused their research on determining whether or not the learning was cumulative within each phase of PBL. 218 students from 11 randomly selected classes at the School of Applied Science in Singapore participated in the study over a three week molecular cell biology unit. These particular students had experience within the PBL approach the previous year, so they were not new the format. Within each phase of learning the students were given a concept recall exercise that measured their recall of the relevant concepts of the unit. The PBL phases in this study included: problem analysis, self-directed learning and reporting. Prior knowledge was measured with a pretest a week before the study and the students took a post-test at the end of each day's problem. The scores of both the pre and post-tests were analyzed as well as the total number of relevant concepts recalled by the students at the end of each PBL phase.

The results of the study showed the student learning in the next phase was impacted by their ability to recall concepts after a phase. More specifically, students' prior knowledge impacted students ability to recall topics after the first phase of study, problem analysis. The study also found that students' prior knowledge influenced achievement of the students all together. While this is not an issue critics discuss for PBL, the continuous nature of the learning may impact students. One problem with this study is that the assessment tools they used limit the ability to draw on the depth and accuracy of a students' understanding of different concepts. The strength of the study is that the tool used allowed researchers to measure student learning throughout the PBL process, not just at the end.

CHAPTER III: DISCUSSION AND SUMMARY

Summary of Literature

The literature reviewed in this study indicates that PBL is a method of learning that can impact students in a variety of ways. While the research indicates overall positive results, there are a few variances found. PBL was found to positively impact the assessment results of students specifically in understanding and content achievement (Atkti & Duruhan, 2019; Celik et al., 2011; Dods, 1997; Nakhanu & Musasia, 2015). Ramli et al. (2018) found that although lower order questions are not significantly different when taught using PBL compared to traditional methods, higher order thinking is higher for students exposed to PBL. While student assessment is increased, it was found that students exposed to PBL showed a higher standard deviation to the learning, indicating a greater variation in students' performance with PBL than the traditional methods (Fatade et al., 2013). Burris and Garton (2007) discovered that students were more successful when taught with supervised study than PBL. Overall assessment results are important in the immediate sense, but retention over time is also an important thing to consider with PBL. Although the initial assessment results may not always indicate higher achievement for PBL, retention is higher for students exposed to PBL (Dods, 1997; Purshanazari et al., 2013; Wirkala & Kuhn, 2011; Wong & Day, 2009).

Students who learn through PBL not only show an increase in assessment results as well as retention rates, they gain skills that help them beyond the classroom. Students are able to apply their learning to new situations and are able to integrate new concepts with prior knowledge better than those who learn through lecture based lessons (Capon & Kuhn, 2004; Wirkala & Kuhn, 2011). PBL helps students grow in skills necessary for success in the 21st century, such as digital literacy, communication, positive behaviors and problem solving skills (Gordon et al., 2001; Sungur et al., 2006; Tarmizi et al., 2010; Wan Husin et al., 2016). As teachers seek to teach students content knowledge for their particular subject, students grow in multiple other ways when exposed to PBL.

The research also indicated PBL may impact the gender difference found in STEM field interests. The research is inconclusive in this area as Brown et al. (2003) indicated that high school students when exposed to PBL resulted in a difference in self-efficacy between male and female students, while Schettino (2013) showed a growth in confidence for female math students when exposed to PBL. Ultimately, it was seen that male and female students achieve at the same level when they are able to compete, work together and learn from one another about math through PBL (Ajai & Imoko, 2015).

Through a variety of studies it is clear that while they may enjoy PBL, students find the shift from a traditional classroom to PBL challenging for a variety of different reasons. Students demonstrate positive feelings about PBL, specifically that they are able to work with others, take responsibility for their learning and gain skills in negotiation, research and presentation (Dods, 1997; Goodnough & Cashion, 2006; Gordon et al., 2001). Students in a classroom taught through this method of teaching show an increase in motivation and engagement, and participate in the lessons not because they have to but because they want to (Ceasar et al., 2016). The positive perceptions of students are accompanied by hesitations when students are required to make a shift into a new method of learning (Tarhan et al., 2008). One thing students communicate is that they are exposed to less content as a result of PBL when compared to traditional learning methods (Dods, 1997). Students also struggle to work with others and adapt to the new roles required of them in PBL (Akti & Duruhan, 2019; Sunger et al., 2006). In summary, some students communicate positive feelings about PBL, and others are more hesitant to the method.

The effects of PBL are overall positive when compared to the traditional method of learning. With this in mind, teachers must take a few things into consideration prior to the implementation of PBL in their own classrooms. Within PBL, there is a required shift in the role of the teacher and the student. The teacher is no longer the instructor, but rather functions as the facilitator of the lessons to support students, provide resources and direct the learning of students (Celik et al., 2011; Yukiymenko et al. 2014). The teacher's role shifts in order to allow the student to take control of their learning by working with other students in their groups, managing the resources and discussing the solutions with their classmates (Yukiymenko et al., 2014). PBL implementation requires that the teacher and the student both understand and participate in their new role in the classroom.

Teachers who implement PBL should consider that the change requires training. Research indicates this training can come in the form of professional development workshops as well as teacher training programs. Hendrix et al. (2002) shows that teachers who attended a PBL workshop were able to learn a lot about the implementation of PBL through a live demonstration of PBL with students and the workshop generated enthusiasm and understanding of PBL. The demonstration of PBL was also important in the teacher training program that resulted in preservice teachers feeling confident in their ability to implement PBL (Wynn & Okie, 2017).

PBL has been researched in a variety of different settings, and the implementation has been examined specifically accompanied by different tools. With the initial implementation of PBL, Henry et al. (2012) found that students desire lectures and guidance from the instructors, but lectures should be avoided as they may impact students' PBL experience. Rather than including lectures in the lessons, it was found that teachers should include a time at the end of each problem that allows students to ask questions before moving onto the next question. With PBL requiring a shift for both the teachers and the students, a variety of tools have been included in the implementation with the hopes of increasing student success. Concept cartoons did not impact the success of students in PBL, but both guided tutors who maintained a more active role in the PBL and the inclusion of knowledge construction impacted students conceptual understanding (Balim et al., 2016; Budé et al., 2011; Yeo & Tan, 2014). Teachers implement PBL can include either conclusion time, guided tutors or knowledge construction as tools to accompany lessons.

The last thing that must be considered when implementing PBL are the challenges that a new method of learning creates for both students and teachers. Students struggle to shift from a passive role of learning to a more active role that requires them to take responsibility for what they learn (Ceasar et al., 2016; Henry et al., 2012). It is a challenge for students to move from a teacher-centered setting to PBL as they are required to maintain more responsible roles in the acquisition of new learning. When a teacher is aware of PBL and how it has the potential to positively impact student learning, they face the challenge of shifting from the traditional approach of teaching to a more student-centered approach (Fatade et al., 2013). Teachers tend to feel a hesitation to make a shift because they must make a lot of changes including choosing a problem, deciding on the amount of structure provided by the teacher, and maintaining the role as facilitator (Goodnough & Cashion). Pecore (2013) also revealed that outside forces such as principle support can impact a teacher's ability to implement PBL. Lastly, learning is cumulative within each phase of PBL and student success is significantly impacted by their prior knowledge of the topic so teachers must consider how to scaffold learning for students with a lack of prior knowledge (Yew et al., 2011).

Overall, there is a positive impact on student assessment results when exposed to PBL. Students are also positively impacted through the retention of learning, ability to apply learning to new situations, an increase in 21^{st} century skills and overall student satisfaction. When PBL is implemented in the classroom teachers should consider the role of the teacher and the student, and seek training to gain the skills required to make that shift. Through the training, teachers should consider challenges for both students and teachers and how those challenges can be overcome through the addition of tools to PBL.

Limitations of the Research

PBL was first introduced into higher education sixty years ago, and abundant research exists on the topic within education beyond the secondary setting. While research has emerged in regards to PBL in the secondary setting, there is a limited number of studies on the topic at the secondary level. The goal of this thesis was to include only sources that studied PBL at the secondary level, but the body of research was limited so a few studies beyond the secondary level were included for a more robust view of PBL. The studies conducted at an undergraduate level by Budé et al. (2011), Celik et al. (2011) and Henry et al. (2012) and were all included as they investigated PBL in physics, engineering and math, which was the area of interest for the author. The studies by Purshanazari et al. (2013) conducted in a medical school setting and by Capon and Kuhn (2004) conducted in a graduate school setting were included because the effects of retention were investigated on the students taught through PBL. Another limitation to the body of research is the effects of PBL in a secondary mathematics classroom. While a few studies do exist such as the studies conducted by Nakhanu & Musasia (2015), Ramli et al. (2018) and Tarmizi et al. (2010), this study had to be expanded to include other disciplines to provide a more complete body of research.

Another limit to the research is how PBL affects students' performance on standardized tests at the secondary level. Yeo and Tan (2014) focused their study on the concern that PBL is not a reliable way to gain content knowledge for students, and rather focuses on the problem solving skills gained through the method of learning. Although some studies found that content knowledge was higher for students who learned through PBL such as Celik et al. (2011) and Nakhanu and Musasia (2015), other studies found that content knowledge was lower, but understanding and problem-solving were higher, such as Dods (1997) and Ramli et al. (2018). There is a lack of studies that compare the traditional method of learning to PBL in regard to results on standardized tests.

One final limit to the research is how does PBL affect students who may not fall under the traditional student demographics. While Gordon et al. (2001) focused on the impact of PBL on minority students, there is a lack of research that studies the impact on students with learning disabilities, or those with social anxiety. There was limited research on students who receive special education services.

Implications for Future Research

There is a small body of research that focuses on the addition of tools to a PBL classroom, such Balim et al. (2016) and the additional of concept cartoons, or Budé et al. (2011) and the addition of guided tutors to PBL. Future research should continue to focus on tools and modifications to PBL to overcome the challenges for both students and teachers. Another area of focus should be on the impact of PBL on the long term retention of both content and problem-solving skills for secondary students. This is a challenging area of research, as retention in the secondary setting is currently measured over months of time, rather than years. Future research of retention of learning for students exposed to PBL over years of time rather than months would be impactful as it would allow teachers to see the long term ramifications of PBL rather than just immediate impacts.

Students in a given class come from a variety of different backgrounds, and do not always fit the typical student profile. A teacher must make changes in the classroom with all students in mind, for this reason future research should be conducted on the impact of PBL on special education students, students with social anxiety and students with different learning disabilities. This area of research should focus on the impact of PBL as it is currently on students in those categories. The research should also seek additional tools and interventions that can be combined with PBL to ensure the success of all students in the classroom.

Implications for Professional Application

This body of research indicates that PBL has the potential to impact student learning in a variety of different ways. The positive potential effects include increase in assessment scores, increase in retention of the learning, and an increase in skills such as problem solving and collaboration. But with the potential positives, it has challenges for both teachers and students that must be considered prior to a complete implementation of the method.

The first thing to consider prior to implementation of PBL is the differing views of the new method of learning by students who have experienced PBL. While some students truly enjoyed taking control of their learning and working with others, other students were resistant to the change and felt the lack of support was harder to learn through. Students also struggled to work collaboratively, and this is especially impactful for students who have potential social anxiety or social struggles. A teacher must look at those challenges for the students based on their perceptions, and plan accordingly on how to overcome the hesitation. Another thing to consider is the wide response to PBL by students. Although the overall results were good, Fatade et al. (2013) found that students responded with greater variance to PBL than the traditional method. This draws on the lack of research on the effects of PBL with students who receive special education services. The goal of a new method of learning is to increase the success of all students, so this should be considered prior to adding PBL to the classroom.

Teachers must also consider how the implementation of PBL will affect their practice. It has been found that the shift from the traditional method to PBL is a challenge for teachers as they must distinguish what problems to use for the learning, balance the level of support they will give students and truly shift in practice not just theory (Fatade et al., 2013; Goodnough & Cashion, 2006). While the idea of PBL is very appealing to teachers, it takes a lot of work and intentional action on the part of the teacher to ensure it is implemented correctly. With the challenge of moving from theory to practice, it is important to consider the role of training in the implementation. Based on the research by Hendrix et al. (2002) and Wynn and Okie (2017), a teacher should receive training, specifically in the form of demonstration to better understand PBL and the role of students and teachers. The final challenge a teacher faces is the support of administrators and parents for the new method of learning. If implementation of PBL is to happen, the teacher should meet with the administrator to ensure support and discuss how the change will be communicated with parents.

Conclusion

In conclusion, problem-based learning has the potential to positively impact student learning in a variety of ways at the secondary level, but should not be implemented without consideration of the challenges for both students and teachers. It is clear that PBL is overall better for students in both acquisition of new knowledge, and the gaining of new skills. Before implementation, it is important to consider the shift in roles required of both the teacher and the student, as well as the challenges the student and teacher face with a new method of learning. The challenges can be addressed through proper training and models by experienced PBL teachers prior to an overall implementation.

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