THE EFFECTS OF COMBINING PROBLEM BASED LEARNING AND TECHNOLOGY

by

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ABSTRACT

This paper reviews the research on the effects of combining technology with Problem Based Learning in a secondary classroom. The data collected shows that students are far more motivated and gain a deeper understanding of their subjects in classrooms where technology supported Problem Based Learning (PBL) is employed. Teachers are best trained in implementing this through developing a solid bases in tech skills, followed by training and implementation of technology-based PBL, which should include software which supports the teacher. Further research is needed to confirm that these methods are as effective for low income and non-white students. ELL students seemed to be particularly responsive to technology-based PBL and further investigation of this is warranted. Studies suggested that this approach should be effective for all subjects, but more research is warranted outside of the sciences, particularly in language arts and social studies.

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CHAPTER ONE: INTRODUCTION

Introduction

One of the most common questions educators encounter in almost any subject is "When will I use this in real life?" Students crave not only knowledge but an application for that knowledge (Keller, J. 1979 and Abbott, M. and Fouts, J. 2002,). The most satisfying accomplishments in life are those that have a measurable impact on our world. The closer the teaching of a skill or knowledge to the experience of using that skill or knowledge in a way which has a real world impact, the more satisfying a student will find their education and the easier it is for the student to stay motivated (Keller, 1979).

At present there are many motivating factors in schools. They are rarely directly related to the ability to function better in the world on a day to day basis. The motivations provided by teacher to their students or developed by students are generally ones that serve a secondary purpose (Nystrand, M. and Gamoran, A., 1991). Examples often cited in a variety of resources include receiving good marks in school, getting into a good college or receiving scholarships, or making ones' parents proud. These are all common motivational factors yet they are either extrinsic motivations unrelated to the actual process of learning or long-term goals that are not related to the immediate skills and knowledge being taught (Ryan, R. and Deci, E., 2000).

Students are best motivated when they feel competent, in control of their learning, and have a connection to others (McCombs, B. and Miller, L., 2006). These are factors that can be effectively addressed by several forms of practical application. When one uses their skills in a way related to the real world they have an opportunity to display and prove competence. Engagement with the outside world will often mean connecting with others and usually means working with their fellow students as well. The use of technology as an integral component further engages and motivates students as noted by Minh Liu in several studies cited below including Liu, Toprac, and Yuen (2009). When students are engaged in practical application it is generally in a form which includes aspects of self-directed learning, allowing the student a satisfying amount of autonomy from their instructor (Corno, L., 1992 and Bolhuis, S., 1996). Technology scaffolds can aid student autonomy as pointed out by Belland, Glazewski, and Richardson in their 2010 study.

Rationale

> I have indeed two great measures at heart, without which no republic can maintain itself in strength: 1. that of general education, to enable every man to judge for himself what will secure or endanger his freedom. 2. To divide every county into hundreds, of such size that all the children of each will be within reach of a central school in it.
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> ~Letter to John Tyler (1810) Thomas Jefferson

Education in the United States is focused on creating responsible citizens capable of participating in democracy and becoming contributing members of society (Jefferson, T. 1810 and Goodlad, J. 1984). The acquisition of knowledge in a vacuum fails to provide any real world context for understanding how to apply what is learned to adult life. Skills learned in a specific setting and context that is solely related to the classroom will not be useful to students except in similar circumstances (Dewey, J. 1916, Gardner,

H. 1991 and Wirkala, C. and Kuhn, D., 2011). As classroom-like circumstances rarely arise outside of schools it is necessary to broaden the context of learning so that it can be applied to other situations beyond the classroom walls (Drucker, P., 1993), or as Alvin Toffler, Futurist has noted, "The illiterate of the 21st Century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn " (Toffler, A. 2001, online retrieval). To this end the following paper will examine ways of bringing together the teaching of a skill or knowledge to the experience of using that skill or knowledge in a way which has a real world impact, motivates and engages students and explores practical applications of the skills and knowledge taught by the educational system.

Historical Background

Practical application has been a part of education since prehistoric times. Its most recognizable form from history is probably the apprenticeship where students learn their trade from a more experienced practitioner while performing useful and relevant tasks for them. Apprenticeships also frequently include classroom or other instructional practices that support and enhance the practical application of skills and knowledge. These approaches are less common in a modern society. The goals of education are no longer simply vocational but focus on creating a citizen who functions in society at large, as a wholly encompassing apprenticeship in the functions of modern life would be impractical. Implementing this approach is no longer appropriate or practical in a modern educational system. The old system's effectiveness, however, can shed insight into implementing similar practices in our modern educational system (Bentley, T., 1998 and Evans, R., 2012).

An important complementary concept that can be found throughout history is that of self-directed learning (Corno,1992 and Balhuis, 1996). This learning style is one in which the student uses the resources around them to develop their own understanding and skills. A formal understanding of this practice would have to wait for thinkers of modern times but the practice has been recorded throughout human history.

Practical application is an educational concept that has earned many supporters as an element to be included in formal education. One particularly important figure from the early Twentieth Century was John Dewey. He supported the concept of immediate experience (Dewey, 1916). Dewey believed that a student's learning needed to have an immediate applicable value and that this should be achieved through hands-on and experimental practices (Dewey 1916).

Jean Piaget and Barbel Inhelder (1969) believed that learning took place through a student being able to develop their own ideas, asking questions they invented, and ideas they wished to pursue. These were similar to the more group-based models developed by Lev Vygotsky (1934). These two thinkers thus developed theories that explained the processes behind the long observed practice of self-directed learning.

The concepts these thinkers had developed lead to an approach known as student-centered learning (Dewey, 1916 and Rogers, C., 1983). This form of learning was focused on the needs of students rather than those of teachers or administrators.

The next significant development in this area came with discovery learning which had its foundation in students understanding the underlying concepts behind the information that was being taught to them (Bruner, J., 1976 and Arends, R.,1997). Here the focus was also on students-centered activities such as student innovation and discovery (Arends, 1997). Students were expected to engage in inductive reasoning and the inquiry process (Arends, 1997). While these concepts were applied to scientific areas by discovery learning's creator, Jerome Bruner (1976) they would come to be used in a much wider sense later in the century (Arends, 1997).

Working from these ideas developed by Dewey, Piaget, and Vygotsky, Problem-Based Instruction (PBI) was developed. Additionally, it was from the concept of social constructivism, the learner/student making his own meaning with facilitation, (Vygotsky, 1934) that PBI gained its collaborative focus. While Dewey had shown the importance of a practical and democratic classroom, Piaget and Inhelder further pursued this in the 1960's. It was from these thinkers' ideas that Howard Barrows created Problem-Based Instruction as a means to develop several important skill areas (Barrows and Tamblyn, 1980).

Limitations

This paper focuses on the core content areas of secondary education (language arts, social studies, math and science), its integration with technology and how student motivation and understanding are improved through giving those disciplines a specific and real world purpose using Project Based Learning (PBL) as the instructional delivery model. Studies which include subjects outside of the 6th-12th grade range will only be included if a sufficient number of those studied were within the target grade range.

This paper also includes an examination of more generalized studies that focus on student motivation and comprehension. These areas can greatly inform the practices that aid student involvement and when blended with practical application can be used to create a curriculum that will produce highly motivated students learning to apply their skills and knowledge to real world situations.

Statement of Purpose

With an approach which keeps a focus toward activities that have an effect on the world outside the classroom, students will be given the opportunity to see how their education provides the skills and understanding they will need in their lives, not only in the future but in the present as well (Keller, 1979 and Nystrand and Gamoran, 1991).

There is a long history of practical application as part of education and it has been given a basis in philosophy (Vygotsky, 1934) and psychology (Bruner 1976, Paiget, 1969 and Gardner, 1991) during the Twentieth Century. In the past fifty years, several teaching models have been developed to support its implementation in a classroom setting. This paper focuses on the effects of the Problem Based Learning instructional model's implementation on student motivation and engagement in the core content areas of language arts, social studies, science and mathematics integrated with technology in secondary classrooms. This includes the more recent addition of technology integrated to support PBL from early work in medical schools which has now then integrated into primary and secondary education. As more and more teachers are coming into the field with technology expertise integration been expanded and enhanced into classrooms across the nation, Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, and Kocaman (2009).

Summary

This chapter provided an overview of the history of inquiry-based constructivist education and explores how this model may enhance the learning experience of students and provide a meaningful and engaging educational experience through a real-world context using Problem Based Learning. It also noted that motivational factors are often extrinsic but the process of student-centered learning provides an intrinsic motivation that is long-term and engaging as noted in 1995 by Wlodkowski and Ginsberg who wrote that,"… engagement is the visible outcome of motivation, the natural capacity to direct energy in the pursuit of a goal," p.19.

Chapter Two addresses a critical review of the literature covering seven themes: Motivation Drives Learning, Problem Based Learning Increases Relevance, Motivation and Achievement, Technology Improves Motivation and Student Engagement, Technology provides a Strong Basis for PBL, PBL is More Effective than Traditional Methods for Skill-based Learning, and PBL and Technology Scaffold Student-centered Learning.

Chapter Three includes a summary of findings, as well as implications for classroom practice and suggestions for further research.

CHAPTER TWO: CRITICAL REVIEW OF THE LITERATURE

Introduction

The first chapter of this work reviewed the development of social constructivist education and Problem Based Learning, as well as the context in which they now exist; the era of rapid technological progress. The need for student centered learning with real world relevance has been a frequent and controversial topic in education for over a century. With the development of Problem Based Learning in the latter half of the Twentieth Century, a codified instructional basis has been developed to deliver relevant and meaningful education to students which teaches them information and skills in a way which is highly motivating. As technology has developed in recent decades new ways of delivering these kinds of educational experiences have become available and as this progress continues more complex and relevant learning experiences become easier to deliver.

Chapter Two is a critical review of literature covering seven themes: Motivation Drives Learning, Problem Based Learning Increases Relevance, Motivation and Achievement, Technology Improves Motivation and Student Engagement, Technology Skills Provide a Strong Basis for PBL, PBL is More Effective at Delivering Skill-based Long-term Learning than Traditional Methods of Instruction and PBL and Technology Scaffold Student-centered Learning.

Motivation Drives Learning

Four studies in this section researched how motivation drives learning through key aspects of engagement in a student's education. The two terms can be viewed as related, although they are not identical as according to Wlodkowski & Ginsberg (1995), engagement is the visible outcome of motivation, the natural capacity to direct energy in the pursuit of a goal. In 2006, Anderman and Gilman found that maintaining high motivation influenced psychological and social functioning as well as leading to higher academic performance and a more positive perception of school. Blumenfeld, Hoyle, and Meece (1988) found that students with a greater intrinsic motivation to learn placed a greater importance on goals around learning and comprehension, while students with less intrinsic motivation focused on goals of gaining recognition, pleasing the teacher, or minimizing effort. Csikszentmihalyi, Schneider, Shernoff, and Shernoff (2003), using a quasi-experimental design, found that student disengagement stems from lack of challenge and meaning. Teachers should use activities that offer choice, reflect personal goals and offer opportunities for success, and that typical teacher initiated instruction such as lectures, do not foster engagement. Nystrand and Gamoran (1991) found that disengagement adversely affects achievement, and that this can also be seen in procedural engagement (turning the pages of the book, helping the teacher with passing out papers, appearing to take notes) has a negative relationship to achievement, while substantive engagement (interacting with the content through discussion, reflective writing, extension and application) has a strong positive effect on achievement. Finally, these researchers found that students have higher achievement when questions are focused on open-ended ideas and what students bring to the classroom rather than on what they are expected to achieve.

Anderman and Gilman (2006) examined the relationship between relative levels of motivation and intrapersonal, interpersonal, and academic functioning among older adolescents in a quantitative study of 654 ninth graders out of a possible pool of 980 in three high schools in separate districts in a Southern state. Students were administered surveys in the school cafeteria, theater, or a classroom. Students were seated far enough apart to avoid disruption to the test and socialization. At least one teacher/administrator and one research assistant were present to monitor student behavior. Researchers used five different surveys to analyze mental health (Self report version of the Behavioral Assessment System for Children, 2nd edition), intrinsic motivation (Children's Academic Intrinsic Motivation Inventory), overall life satisfaction (Students' Satisfaction with Life Scale), satisfaction with family and friends (Multidimensional Students Life Satisfaction Scale), and peer acceptance, inclusion, and active participation in school life (Psychological Sense of School Membership survey). Students were then organized into peer groups consisting of ten members who had all known each other for at least a year and rated each other on a series of questions about how well they participated in school. Students self-reported GPAs, due to district policies. However, the reported GPAs did not significantly depart from the school's grade-point distribution.

Students reporting significantly lower adaptive motivation (intrinsic motivation, self-adequacy, and higher external locus of control) appeared to display pervasive adjustment problems that were not found with students who had higher adaptive motivation. Students in the high adaptive motivation group reported higher levels of self-esteem, global satisfaction, family satisfaction, school belongingness, and GPA, while having significantly lower levels of depression, anxiety, and social stress in comparison to students in the average motivation group. The findings suggest that maintaining high motivation influences psychological and social functioning, in addition to higher academic performance and school perception.

Students in the low adaptive motivation group were rated as more likely to start fights and less likely to help others and do well in their school-work than those in the average or high motivation groups. Peer observations reported in the study confirmed the self reported data. This supports the researchers' earlier findings that motivation is related to social interactions. Findings suggest that perceptions and actions of peers toward other students may intensify these effects in relation to adaptive motivation.

The study consisted of survey data from the students and their peers, which was then correlated with group assessment of the students in the study. This allowed for cross-referencing to check on peer and self evaluations, but as these views often build on one another there should be some awareness that these findings are built on opinion and self-reported information and not observation. With 654 subjects, this study had a very large sample size, lessening the chance of a population-based type one or two error. With a 67% return rate out of a pool of 900 students a significant percent self-selected out of the study, eliminating data on that section of the population which may have influenced other factors in the study. The population was disproportionally white, with Asian and Hispanic students underrepresented but with African American students representational of national demographics. Grade point average was self reported but consistent with school-wide grade point average, which indicates both accurate reporting and a cross section of each school's student population consistent with overall academic performance.

The majority of findings were significant at the $p<0.001$ level, with a few only significant at the $p<0.05$ level. All findings would be considered statistically significant with the main difference in adaptive motivation having an f value of 8.34 and $p<0.001$.

The findings suggest that maintaining high motivation influences psychological and social functioning, in addition to higher academic performance and school perception. Students in the low adaptive motivation group were rated as more likely to start fights and less likely to help others and do well in their school-work than those in the average or high motivation groups. Peer observations reported in the study confirmed the self reported data. This supports the researchers' earlier findings that motivation is related to social interactions. Findings suggest that perceptions and actions of peers toward other students may intensify these effects in relation to adaptive motivation. The findings also suggest that maintaining high motivation influences psychological and social functioning, in addition to higher academic performance and school perception. Peer observations largely mirrored self-reported data. This supports previous assertions that motivation is related to social variables. Findings suggest that perceptions and actions of peers toward other students may intensify these effects in relation to adaptive motivation and that high adaptive motivation is related to important differences in psychological, psychosocial, and academic functioning compared with those in the average or low groups.

Blumenfeld, Hoyle, and Meece (1988) asked what motivational processes fostered a high level of cognitive engagement in classroom activities? This question was addressed through a qualitative study of 100 fifth grade and 175 sixth grade students from ten classrooms and were assessed through a series of surveys and six lessons taught by 5 teachers with more than 5 years experience, 3 female and 2 male. The Scale of Intrinsic

Versus Extrinsic Motivation in the Classroom survey was administered as an initial assessment of students' intrinsic motivation. Items were averaged from three sub scales; preference for challenge, curiosity, and independence. General attitudes about science were measured with 12 items adapted from the Attitudes Toward Science Survey. This measured interest and enjoyment as well as general perceptions about science. The Science Activity Questionnaire included 15 additional items designed to assess student cognitive engagement. Goal orientations were measured by the Science Activity Questionnaire after each of the six lessons.

Researchers found that content engagement related most directly to student goal orientations. Students who placed a stronger emphasis on task-mastery goals reported more active cognitive engagement in learning activities. To a lesser degree, social/ego goals related to task-mastery goals. Students with strong concerns about their abilities or evaluation could increase effort minimizing strategies. Intrinsic motivation had a direct impact on engagement patterns but a substantially greater indirect influence through goal orientation. Students with a greater motivation to learn placed a greater importance on goals implying that learning and comprehension where important. Students with less intrinsic motivation focused on goals of gaining recognition, pleasing the teacher, or minimizing effort. It should be noted that academic ability did not predict goal orientation or cognitive-engagement patterns. This may have been due to a use of general ability and not content specific measures. Individual intrinsic motivation and science attitudes had a greater effect on social/ego goals in small groups than in whole class activities.

The use of a Likert scale, which is standard, was and thus the tool used for gathering the study's data can be considered reliable. The use of standardized test scores as a measure of general academic ability has some validity but is also limited in scope, however. The study's results were significant at the $p<0.001$ level, giving the results a high level of statistical significance. However, while a detailed explanation of their analysis was given, no actual F value was provided, leaving the statistical data incomplete. All other analysis was highly detailed, making this less of an issue than it would be under normal circumstances.

In summary, student self-perceptions, needs, and interests played a critical role in student motivation and goal setting. The reliance on the surveys and questionnaires over observation allowed for the collection of data that could then be referenced with the other surveys to develop conclusions about student motivation. Reliance on this method narrows the interpretation of the data, as other potential factors could not be considered.

Csikszentmihalyi, Schneider, Shernoff and Shernoff (2003) in their quasi-experimental research design asked if learning situations featuring high challenges that were matched with high skills associated with high engagement? Data was collected in three waves, 1992-93, 1994-95, and 1996-97 from thirteen high schools across the U.S. for a total of 526 students over the five year period. The Experience Sampling Method (ESM) was used for this study, which is designed to measure the location, activity, as well as the affective and cognitive experiences of students at random internals. It is especially useful for measuring subjective experiences of interaction with an environment. Students carried log books with enough ESF forms to respond eight times a day for one week and were prompted to fill them by pagers which would go off at semi random intervals. It was found that tasks that are too easy or difficult do not foster a sense of engagement. Challenges that are just above student skill level seem to result in the most engagement. The need to learn new skills in order to complete tasks is a good measure of this and reflects their Zone of Proximal Development (Vygotsky, 1934).

The immediateness of the surveys caught students in the middle of activities, which may have effected engagement, but also allowed a more accurate reflection of how students felt about their material. The demographics skewed over 60% white and over 60% female, and thus might not be as accurate a representation of U.S. demographics as one would hope, but other groups were still included in the data.

Sample size was disproportionately female, middle or upper income, and white, giving it some issues with generalizability to other populations. Other groups were represented but not at the rate they are in many areas, especially urban and rural schools. Likert scale surveys and ESF forms provided standardized assessment tools with known validity. The p values were very low, giving the study a high level of statistical significance.

Results also showed that higher challenge was associated with higher engagement versus lower challenge with a t value of 9.83 with results significant at the $p<0.001$ level. The higher perceived skill level was also correlated to higher engagement with a t value of 10.89 and was significant at the $p<0.001$ level. Combining the various engagement techniques gave a composite score with an F value of 83.12 which was statistically significant at the $p<0.001$ level.

The results found that balancing the challenge of activities and the skills needed appear to have profound effects on student engagement. The perception of having control and the relevance of the activity were also important factors to engagement. Collectively this suggests that student disengagement stems from lack of challenge and meaning, typical teacher initiated instruction such as lectures. To foster engagement teachers should use activities that offer choice, reflect personal goals, and offer opportunities for success.

Nystrand and Gamoran (1991) asked what kinds of instruction foster student engagement with literature and what were the effects of such instruction on achievement. This qualitative study drew subjects from 58 8th grade classes where reading was the primary activity; in this study they were termed English classes, regardless of local naming policies. These classes were in 16 Midwestern schools. In composition one small-town and two rural schools only included European American students, four were suburban with student bodies mostly comprised of European Americans with Upper-Middle class backgrounds. Nine of the schools were urban and had mixed ethnicity and socioeconomic backgrounds. Ten these schools were public middle schools or junior highs while the other six were Catholic K-8s. Of the 1171 students enrolled in these classes, 1041 took part in the full year of the study.

Data was drawn from surveys given to both teachers and students as well as classroom observations. Questions were coded based on the source (teacher or student), response, uptake, authenticity, and level of evaluation. Authentic questions were open, semi-authentic offered a range of responses, and inauthentic ones were those where a specific answer was being looked for. Uptake was rated based on if the question required incorporating an earlier answer. Level of evaluation was based on when teachers acknowledged that a student's response to a question had changed the direction of a discussion. To score well the teacher had to respond with more than generic praise.

Classes were observed four times, twice each semester by a trained evaluator who observed classroom instruction. The focus was on how much time was spent on different kinds of activities (lecture, discussion, assignments, etc.) and recording and coding both teacher and student questions based on authenticity, uptake, level of evaluation, etc. The data from these four observations was averaged. Three hundred eleven episodes were observed during 227 class sessions. An episode was considered an activity that focused on a specific objective or purpose. These were usually made up of two or more activities, such as a question and answer interspersed with lectures followed by a homework assignment. Substantive engagement was measured based on authenticity, uptake, and level of evaluation.

Academic achievement was analyzed pre- post research using the students' 7^{th} and 8^{th} grade NAEP writing and reading scores. Classrooms were observed by experienced research experts in student engagement 4 times each over the course of a year.

The study had a sufficient amount of data to generalize the findings to similar populations. Observations and surveys focused on three areas: student background, procedural engagement, substantive engagement. Students self-reported on their family backgrounds as well as their perceptions of engagement. Teachers also reported their perceptions of student engagement. Researcher observations on four separate classroom visits were triangulated with the engagement reports of students and teachers to provide validity. Data was analyzed using regression equations for each of the research areas.

Strengths of the study included a pool of students (1041) who took part in a year-long study in 58 classrooms in sixteen schools in the Midwest. Other strengths included researchers who were experienced in the research procedures including the observation protocols for student engagement and the use of regression equations based on observations, surveys by students and teachers and academic test scores (NAEP).

The results of this study showed that disengagement adversely affected achievement, procedural engagement had an attenuated relationship to achievement, and substantive engagement had a strong positive effect on achievement. Students had higher achievement when questions were focused on open-ended ideas and what students brought to the classroom rather than on what they are expected to achieve.

As shown in this section, motivation drives learning through engagement. The first piece of this was shown by Anderman and Gilman (2006), whose study showed that students who maintain high motivation are better able to function in school and had improved performance as well as perception of school. Further, students who have higher intrinsic motivation placed a greater importance on goals where learning and comprehension were important while those who were not as intrinsically motivated focused on gaining recognition, pleasing the teacher, or minimizing effort (Blumenfeld, Hoyle, and Meece, 1988). This showed that student goals are more aligned with real long term learning when they are motivated to learn by personal desire to engage with the content, while motivation based on external factors tends to lead to students who are status oriented yet avoid putting in effort when possible. Thus it is clear that engagement must be kept high through those means that are available to teachers, as procedural engagement has an attenuated relationship to achievement (Nystrand and Gamoran, 1991). This is best done through substantive engagement, which has a strong positive effect on achievement, which is achieved through questions which are focused on open ended ideas and what students bring to the classroom, while student disengagement stems from lack of challenge and meaning (Csikszentmihalyi, Schneider, Shernoff, and Shernoff, 2003; Nystrand and Gamoran, 1991). These factors and the research of Csikszentmihalyi, Schneider, Shernoff, and Shernoff (2003) showed that to foster engagement teachers should use activities that offer choice, reflect personal goals, and offer opportunities for success, which as will be shown in the next section, is effectively achieved through Problem Based Learning.

Problem Based Learning Increases Relevance, Motivation and Achievement

Five studies examined how motivation and achievement were improved through the use of Problem Based Learning (PBL), particularly by increasing the relevance of the instruction, which is the key to student engagement, as outlined in the previous section. Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) found that while PBL takes more time to plan and that managing small group work was reported as the most challenging part, students were more engaged and told the teachers that the learning was more relevant to them than traditional methods, which caused teachers to conclude that the effort of overcoming the challenges was justified. Williams, Hemstreet, Liu, and Smith (1998) found that there was a significant level of increased achievement by the PBL groups over the control group. Rotgans and Schmidt (2010) found that situational cognitive engagement is more a function of the learning event than a feeling of learning autonomy. Abbott and Fouts (2002) found an inverse correlation between income and both constructivist teaching and achievement, and that constructivist teaching's effects are small but positive. Sage (1996) found that when using PBL there was a successful engagement of elementary students school students and that teachers redefined how they teach and their views on what students need to know and are able to do.

Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, and Kocaman (2009) asked how teachers characterized the challenges of technology-enhanced PBL, what strategies had teachers used to address these challenges, why teachers persisted despite the challenges associated with PBL, and what rewards were associated with PBL. These questions were addressed through an exploratory qualitative case study of five female middle school teachers, experienced with PBL and technology training. All were from the same rural site in the Midwest. Two were language arts teachers; one was a science teacher, one a math teacher and one ELL teacher. The language arts teachers had attended almost every training offered by the grant over five years. The ELL teacher had attended training in year four only. The researchers noted the sample was small as well as limited because it was homogenous: females from the same school, who all had experience with PBL.

The study was designed to examine teachers' perceptions of challenges and strategies to overcome the challenges of PBL instruction. Five teachers were specifically sought out in a rural middle school with a five-year technology grant that incorporated PBL into technology in all content areas. All had participated in workshops in both PBL and technology integration. Research was triangulated using individual interviews 45 minutes in length prior to the start of the year, a focus group with 4 of the 5 teachers (one was on maternity leave) in the fall (60 minute duration). The three areas focused on during the interviews were: planning, implementation, and assessment of PBL. An interview guide was constructed based on the research questions. Three questions were developed for each of the three areas of focus (planning, implementation and assessment).

Four to six informal classroom observations were held during the year. The number varied from class to class due to researcher availability. Researchers were looking for evidence of PBL strategies as defined by the research and noted in the interviews by the teachers as being implemented in their classes. They were also looking for the way the teachers overcame their self-identified challenges to PBL implementation and how they persisted in spite of those challenges. Content areas included: math, language arts, science and an English language learner classroom.

Teachers reported that PBL takes more time to plan. They addressed this by going through the process themselves to anticipate students' needs, taking time up front to find relevant resources and they kept the units small using only 2-3 class periods most of the time.

Managing small group work was reported as the most challenging part. Observations confirmed that teachers did not have many strategies for the non-engaged students. Intentionally forming groups based on interests and/or mixing ability levels were used as well as learning styles, student choice and random combinations. In every classroom researchers observed at least one or two students working individually. Teachers described using a variety of strategies to support all students during PBL units including direct instruction mini-lessons on content they needed, creating a website with links to resources and daily checks to keep students on task. Technology failures were also reported adding to the challenge of more time than traditional models.

A variety of tools were reported for assessment. Student reflections, rubrics, and group presentations were all noted. All reported that meeting state standards were a goal as well. They used checklists to assure these standards were being met. A weakness in the study could be the number of teachers being small at 5. However, these teachers were well experienced, all having used tech-based PBL strategies with at least five years of experience. With individual and group interviews as well as classroom observation the study collected a large cross-section of data to base their conclusions on. Observations were conducted over a year period, lessening the observer effect. The semi-structured nature of the interviews gave the researchers a guide to follow while allowing some flexibility in their questioning. This may also have resulted in some inconsistency in interview data gathered between subjects however.

Anecdotal findings included meeting many of the state standards, although the state tests were not used in this study as part of the results. Other findings for overcoming challenges included: creating web lists ahead of time, revising units and using them the next year, using questions from local and current events, use of multiple grouping strategies, assessing with rubrics, allowing students to struggle, and on-going assessment.

All five teachers reported that students were more engaged and that students told the teachers that the learning was more relevant to them than traditional methods. The teachers felt that this alone was worth the effort of overcoming the challenges of implementing PBL. The researchers concluded this was why all five persisted in using PBL units. The researchers also concluded that the strategies these teachers used to overcome the challenges could be shared with novice PBL teachers and that these five could be mentors to novices at their school. Because of the variety of content areas observed, the researchers concluded that PBL was effective in all three content areas. The researchers noted that it was not easy for the teachers to recall their early frustrations implementing PBL. Future research will include a variety of teachers including those who have dropped PBL and those who are novices.

Williams, Hemstreet, Liu, and Smith (1998) asked what is the effect of the computer supported problem-based learning environment on the achievement of middle school science students, what is the effect of the computer supported problem-based learning environment on middle school students' attitudes toward science, and is there a relationship between students' math or reading ability and their achievement in the problem-based learning environment? This was addressed through a mixed method study using both qualitative and quantitative data.

The study was of 115 middle school students ranging in age from 12-14 (65 female, 50 male) and took place in a medium-sized city in a suburban Southwestern community. There were three groups, 59 students in a computer-supported PBL environment, 38 students studying in a paper-based PBL environment, and a control group of 18 students in a traditional, mostly lecture setting. Demographics were 22% white, 66% Hispanic, 12% African American.

The researchers used software and paper PBL curriculum that examined micro-organisms in a lab setting. The lab was 'virtual' in the software delivery model. The software was from Holt Reinhart as was the paper curriculum. Students in the control group covered the same content in a traditional mostly lecture setting. Students' use of the software and paper PBL supports as well as use of PBL process steps were observed by the researchers who analyzed their written observations.

Students were also selected for post-PBL interviews to discover what they liked and disliked about the learning environment, what they found most useful in the delivery model and what they thought about the process they experienced in general. These interviews were to help support the other data.

The effect of the computer supported problem-based learning environment on the achievement of middle school science students was measured using pre and post-tests for the unit on microorganisms with all three groups. It was found that there was an effect on the achievement gains for the two PBL groups. All groups increased their content achievement from pre to post-tests. The gains for the two PBL groups were significantly higher than for the traditional lecture control group. However, the difference in gains between the two PBL groups was not significant.

The effect of the computer supported problem-based learning environment on middle school students' attitudes toward science was examined with data collected from pre and post attitude questionnaires. There were 14 questions on the questionnaires. The result was that there was not a significant impact on the students' attitudes toward learning science for the two treatment groups.

The relationship between students' math or reading ability and their achievement in the problem-based learning environment was examined using the state assessment (TAAS) in a regression study (using past scores for all 3 groups) and a post-TAAS after the PBL and traditional unit were completed. Analysis of assessment scores for reading and math compared to achievement on the content achievement scores indicated that there was a more significant relationship between reading ability and success in a PBL environment than there was for math.

The results for this study had a fairly strong statistical basis. The difference in size between the groups is an issue, but mathematically the samples showed significant difference between PBL and traditional instruction. The results for the increase in pre and post achievement scores had an $F(2, 96) = 5.50$ with a $p < 0.01$, while the difference in gain between the computer and control group, and the paper and control group were significant at the $p<0.05$ level.

Rotgans and Schmidt (2010) asked to what extent autonomy in problem-based-learning (PBL) results in cognitive engagement and how does cognitive engagement develop as a function of the learning process and to what extent does it determine subsequent levels of cognitive engagement during a one day PBL event. The questions were addressed in two quantitative studies. The first study involved 373 polytechnic students with an average age of 20. The exploration sample of the validation study contained 61 students and the conformation portion of the study contained 312 students. 62% of the exploration sample were female, while 52% of the confirmation sample were female. All subjects were enrolled in science-related modules at the polytechnic school located in Singapore. The second study involved 208 students from an applied science module at the same school, 61% of whom were female with an average age of 20.

The first study was conducted through a four item questionnaire given to students after they had engaged in theory construction and generated learning goals. This was first done with the exploration sample and then the conformation group, allowing for cross-validation of the study. The second study used the same methodology but on a single group. This questionnaire measured the students' situational cognitive engagement.

Students' course grades were also examined. These were based on in-class performance and written tests.

In study one, the questions were administered one time to both groups. In study 2, the group of 208 were given the questions 5 times at different stages of the one day PBL project. The first time was when they generated their learning goals for the project, the second after students did initial research, the third after discussing how their goals met what they had found in their research. The fourth time they were assessed with the same questions was after a two hour self-study (PBL work) and finally after students shared their findings and discussed if they had met their learning goals once again.

These were all based on the second study since the first was to validate the measurement that was going to be used. Study two found intercorrelations between the five measurement occasions (4 questions repeated per the phases referenced above) were strong, ranging from .15 to .88. Engagement was highest during the third measured phase and the fourth phase when students first discussed their initial findings and how they compared to their personally set goals, then again when they presented their findings to each other and their tutors. Engagement did not increase or decrease with their presentations. This did not support the original hypothesis that student engagement would be a wave-like pattern based on being with the group and breaking away. It did increase during the day and then stayed at the higher level for the presentation phase. The conclusion was that situational cognitive engagement is more a function of the learning event than a feeling of learning autonomy. The original hypothesis (see findings) was not supported. A new hypothesis has been proposed: Situational cognitive engagement is a direct function of a students' knowledge construction which leads to increased learning choices.

The measurement used (4 questions) was validated by both an exploration sample and a confirmation sample of students at the same school in the same science content area with the same average age prior to the second study which tested the researchers' question about student engagement. The researchers propose that this measure could be used by others investigating student engagement. The second study was not replicated. It was also based on one PBL project that lasted only one day. Also, the researchers noted that further research needs to be carried out to test how autonomy and the students' factual knowledge are related and develop during the stages of student learning in PBL. Cognitive engagement findings in study number two were significant at the $p<0.01$ level, with an F value of 47.53.

Abbott and Fouts (2002) asked what the direct and indirect effects of social constructivist teaching and poverty are on student learning. This qualitative study covered 669 classrooms in 15 elementary, 8 middle/junior high schools, 9 high schools and 2 technical schools. It was designed to provide a representative sample of classrooms from social studies, mathematics, and science and language arts/English content areas. The number of classrooms observed per school ranged from 6-54. The final sample removed alternative schools leaving 28 schools from which the data was drawn. All schools were within Washington State.

The study examined evidence of understanding of materials in low-income student populations and the effects of social constructivist methods on student achievement within that population. This was done through classroom observation for gathering evidence of social constructivist methods, using an observation study. Student understanding data was based on School Level WASL scores of 4th, 7th, and 10th grade students.

Classroom observations where made over four months and data was taken using the Teaching Attributes Observation Protocol (TAOP), which is based on a conceptual framework of constructivist teaching and learning. The criteria included examinations of student work to see if it engaged student understanding, inquiry based activities, application to real world contexts, active participation, use of diverse student experiences, curriculum designed to develop depth of understanding, and assessment tasks which allowed the use of higher-order thinking. The model tested against three variables, low income, constructivist teaching, and student achievement. The goal was to understand the variance in achievement accounted for by constructivist teaching beyond the influence of low income.

Each school received three achievement scores based on writing, reading, and mathematics. A holistic score was also given for each classroom. A few of the schools had both 4th and 7th grades and their scores were assigned based on the size of those grades. These were drawn from Washington Assessment of Student Learning (WASL) scores.

The study found an inverse correlation between income and both constructivist teaching and achievement. The first was expected based on earlier studies. It was of noted that schools with more low-income students also had lower constructivist teaching scores on the TAOP.

An incremental partitioning was performed on the achievement, low-income, and constructivist teaching variables. When the low-income is accounted for, constructivist teaching contributes between 3% and 4% of the variance in achievement. The p value for these findings was less than 0.001, however no f or t value was provided. The conclusion was that the effects of constructivist teaching methods are small but positive, though it should be noted that achievement was defined as having a high score on the state standardized tests.

Sage (1996) asked what the characteristics of PBL as a curriculum and instructional strategy are at the K-8 level and what effects of PBL upon students' learning in the areas of content and thinking skills are. These questions were addressed in qualitative case studies. The study included three classes in two schools in two separate districts. One was an elementary school where PBL was used by most teachers at least in one unit a year. The other was a middle school where some staff members used PBL on occasion while others did not use it at all. The two staff members studied here used PBL exclusively for their teamed/integrated 8th grade language arts and science students.

The elementary school students were in two classrooms taught by two different teachers. One class was a combination 1/2 class and the other a 3rd/4th grade. There were 560 students in the elementary school. The researcher did not provide the number or demographics of the students in the two classes. There were 55 8th grade students in the combined middle school classroom studied. These schools were part of a group that belonged to the Center for Problem-Based Learning in the Chicago area.

Data included classroom observations (video-taped) during PBL. Semi-structured interviews with a small group of students in each of the three classes also took place. The three teachers were also interviewed before, during and after the PBL unit was completed. A collection of student work was examined and included the student log, notes and other materials such as letters composed to experts. Teacher reflections came from the researcher's notes and informal conversations. Focus group interviews with the teachers and student and parents are to be a follow-up to this preliminary research report. Pre and post-testing of student content knowledge was also added but the researcher did not include these results in the paper.

Student engagement varied. The elementary students were engaged from the beginning. This may have been since the former elementary principal presented the problem of her flower garden at the school not doing well and challenged the students to find a solution. The middle school students were not initially engaged. The teachers noted that this was not unusual. As the students read more and had experts on their ecology problem into the school they became more engaged with the topic and the researcher observed that the realization that they could impact the environment at their middle school seemed to be the catalyst for engagement for many students.

Management of the PBL work varied. At the elementary level students were able to choose their groups for both the research and presentation portions. At the middle school level the team teachers did the group selection.

All teachers participating noted that the time spent developing these units were a challenge. The researcher noted in her own research the use of published PBL units seemed to lead students to conclusions rather than keeping them open-ended and although they saved time they did not have the same power to engage students that real world problems in their environment provided.

Adult stakeholders interviewed after the presentations noted being impressed by the depth of knowledge the students displayed. The teachers noted in their interviews that PBL has caused them to re-define how they teach and view what students need to know and be able to do.

This was some of the earliest research on PBL at the K-8 level. The researcher was able to use qualitative research to identify some of the characteristics of what worked at the elementary and middle school level and made note of the effects the curriculum had on teachers as well as students. The findings are mostly relevant for how one conducts PBL and the impressions of staff and students than answering an outstanding questions. This paper ended up being more of a touch stone for further exploration than a definitive piece that stands on its own.

As shown above, five separate studies found that PBL had a positive effect on learning and engagement. As found by Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009), when PBL was used students were more engaged and told the teachers that the learning was more relevant to them than traditional methods. As established in the previous section, engagement and relevance are key to student success and learning. Sage (1996), as well found that PBL was successful engaging elementary students school students, though the same level of success was not achieved with middle school students. There were also variations in implementation, which may account for this difference. Rotgans and Schmidt (2010) found that the PBL format was effective at continues engagement regardless of group or individual tasks, though the study only covered this as a one day phenomenon. As addressed in later sections, tying other engaging elements, specifically technology, to PBL provides a potent combination for increasing student engagement.

Abbott and Fouts (2002) found that the effects of constructivist teaching were only small but positive, this review's focus is not on all types of constructivist methods, but specifically Problem Based Learning. They did address an important issue to note, however, which is an inverse correlation between income and both constructivist teaching and achievement. Further of concern is that teachers found that implementing PBL required significantly more time to plan and execute (Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman, 2009). Providing tools to lessen the amount of planning time for teachers and aid in structuring these activities can make these learning experiences more accessible. Technology is one option that greatly enhances these goals, though this implementation would likely require a grant system so that the low-income districts could participate at the same level as those who were economically advantaged.

Technology Improves Motivation and Student Engagement

Seven studies in this review dealt with how student motivation and engagement were increased through the use of technology in the classroom. Ertmer, Ottenbreit-Leftwich, and York (2007) found that surveyed teachers were committed to using technology because they believed it increased student engagement and student learning. Lee and Erdogan (2007) found that delivering science curriculum through introducing socio-scientific issues using technology greatly improved student motivation for learning science. Liu, Toprac, and Yuen (2009) found that the computer game *Alien Rescue*, a software based PBL tool, was effective at engaging students in collaborative problem solving and challenged them intellectually. Liu, Hsieh, Cho, and Schallert (2006) found that computer-enhanced PBL environments increased self-efficacy for learning science significantly, that self-efficacy has a correlation with a positive attitude toward science, and that self-efficacy was a significant predictor for achievement in science. Morgan (2008) found that using an interactive white board improved student engagement, positive classroom behavior, and that male students' behavior and engagement improved, eliminating the gender gap in these areas. Lambic (2011) found that teaching mathematic concepts through software and game design greatly improved motivation for learning mathematics. Koszalka, Grabowski, and Younghoon (2002) found that teachers considered the materials flexible, used more of the resources as they became more familiar with this online approach, and that their attitude towards this approach was more positive as a result of using these resources. Additionally student interest in a career in science significantly increased, and parents' perception of their child's school as delivering high quality science improved, and parents also saw the use of science resources as increasing.

Ertmer, Ottenbreit-Leftwich, and York (2007) investigated the perceptions of exemplary technology-using teachers regarding the factors that have most influenced their success, and to what extent exemplary technology-using teachers perceive intrinsic versus extrinsic factors as being more critical, and which teacher characteristics, if any, are significantly related to exemplary technology use. These questions were addressed in a mixed method study.

Researchers began with an online anonymous survey to explore the perceptions of exemplary technology-using K-12 teachers. This was defined by their receiving a technology award from one of 5 different Midwestern technology education associations during the past 15 years. The 1-15 year award span ensured a pool of subjects ranging in teaching experience rather than a narrow range of classroom experience integrating technology. The majority of the subjects were female (16 of the 25). Teaching experience ranged from 3 to 32 years with a average of 16 years. 20 of the 25 had completed their masters' degrees. About half had been teaching 13 years or less. All rated themselves as very strong or strong in their implementation of technology in their classrooms. Originally the researchers had a pool of 48 potential participants. The pool was narrowed to 25 award winners who responded to the original and follow-up reminder emails to participate in the survey.

The survey included 18 items. Expert reviewers provided suggestions for the survey. These experts included an elementary principal and an educational technology professor gave suggestions for improving the survey. The researchers used their suggestions in the final version. Six of the questions were demographic questions and two were 20 components scored on a 5-point Likert scale. There were also 8 open-ended items and one checklist of 9 items. Participants also rated their perceptions of the importance of intrinsic and extrinsic factors contributing to their technology use in the classroom. These factors were listed and responses were rated on a 5-point Likert scale. The survey was based on similar surveys found in the literature from their earlier research. The first data for analysis was that relating to exemplary technology-using teachers' perceptions of the factors that contributed to their technology integration success.

Data analysis included calculating means and standard deviations for each of the factors included on the survey relating to teachers' perceptions of what influenced their technology integration success. These factors were then ranked from highest to lowest.

To determine whether the intrinsic or extrinsic factors were more influential a paired samples t-test was used to compare teachers' perceptions. Extrinsic factors included professional development, technology support as well as support of peers and administrators, hardware and software access. Intrinsic factors included inner drive, personal beliefs, commitment, confidence and previous success with technology. These results were triangulated with the survey's open-ended responses regarding the same topics.

Teacher demographics such as number of years teaching, gender, current teaching assignments and degrees earned were also collected and correlated to the survey results. Personal beliefs and inner drive were rated the highest as factors most influential. Both of these were intrinsic factors. The least influential factor was pre-service professional learning even when the 'not applicable' answers were removed. Nine teachers noted that pre-service technology training was not applicable. Researchers noted these were the most experienced teachers and that the class may not have been available to them.

A paired-sample t-test was conducted to determine if there was a significant difference between the teachers' rating of intrinsic versus extrinsic influences. The rating for intrinsic factors was significant ($p < .001$). Factors that exemplary technology-using teachers rated as the most important were intrinsic factors such as confidence and commitment to technology use. Extrinsic obstacles such as technology support were not rated as highly. The researchers noted that this may have been because of their commitment and belief that technology was important to enhancing their students' learning. All teachers rated the most influential extrinsic factor as continuing professional development (rather than pre-service courses).

In the open-ended questions the majority of the participants responded that they were committed to using technology because they believed it increased student engagement and student learning. Teachers with more than 13 years experience rated more factors as being moderately or extremely influential. Teachers with less teaching experience seemed to require less technology support. The researchers note that this could be due to less formal technology training for the more veteran teachers.

The pre-selection method included an anonymous online survey regarding the perceptions of technology proficient teachers and the use of technology integration in their classrooms. This was done by a research team from a large Midwestern university. The same team conducted the research. Their selection method was based on a pool of teachers who were nominees for one of five different Midwestern technology awards. This may have biased the selection process, limited the number of applicants by only using the award nominees. In addition, the pool became smaller because only those who responded that they were interested in participating in the study from this award pool were part of the selection process.

This was a small sample size according to the researchers with only 25 participants. A possible strength, however, is that all of these participants were presumably proficient in technology. Their experience ranged from three to thirty-two years of teaching and twenty of the twenty-five had their master's degrees. Sixteen were female. All rated themselves as computer proficient.

Researchers used qualitative and quantitative surveys with a large amount of data resulting from the 18 item survey which included six demographic items, 2 Likert Scale items, 8 open-ended questions and a checklist. The 5-point Likert scale, however, could have been confusing to participants and a weakness in the results because the '1' on the scale was a choice for not applicable. Reviewers were well-qualified in research processes as the team consisted of two doctoral candidates and one university staff member.

A Cronbach alpha of .76 from the survey results indicates a moderate reliability. Conclusions reached on the importance of extrinsic factors had a significance of $p<.001$ with a t of 7.23 from the 25 participants, giving the results a very high level of reliability.

The small number of participants could be considered a weakness of the study. However, the extremely low p value could be seen as off-setting this low number of participants.

Both intrinsic and extrinsic factors were examined regarding the success of technology integration by these teacher participants. Intrinsic factors such as commitment, beliefs and confidence from earlier success with technology were measured against extrinsic factors such as professional development opportunities and support from peers, administrators, technology support and parental support. A t-test was used as part of the examination of whether years of experience influenced intrinsic versus extrinsic factors perceived as more important. Survey results provided triangulation data. Another interesting finding was that when professional learning was compared to the length of experience of the teacher participants, those who had been teaching longer was significantly correlated to the importance of professional learning ($r = .43$. The researchers noted that this could be a result of younger teachers with less experience having more familiarity with technology in general and therefore relying less on professional development than those who were older.

Intrinsic factors resulted in the highest ratings with M = 4.84. Professional development that was on-going rated the highest for extrinsic factors. However, preservice professional development scored the lowest of all the factors with M = 2.69. In order to analyze the data to see if there was a significant difference between intrinsic and extrinsic factors a paired sample t-test was done. The results indicated that intrinsic factors were significantly higher with $p<.001$ as noted earlier.

In conclusion, the researchers were able to identify factors in the development of exemplary technology-using teachers. Using these factors (beliefs, practices) they plan to build on these to help develop other exemplary teachers through focused both pre-service and on-going professional development. They will also use mentors who have the same characteristics as the participants. They also noted that a larger number of open-ended items should also have been included. Follow-up interviews and observations would also have enhanced the study. There are plans to do more research using these recommendations.

Morgan (2008) asked what is the effect of the interactive whiteboard (IWB) on student behavior as an indicator of engagement in the learning process? This question was addressed in a quantitative study of 226 junior high school students in 3 teachers' classes – 2 at one school and one at another took place in the research. Students were observed over six weeks with one observation per week. Three observations were pre-IWB and three were during its use. Two teachers – one at each site used the IWB and one teacher did not. This was the control group. Before and after the use of the IWB students were given surveys that measured their perception of their attitude toward their own engagement and learning. Students were also observed using a task-engagement checklist. The surveys were compared to the actual observations of engagement and mathematically analyzed to see if there was a positive correlation. The number of teachers was small, and thus could have affected the outcome of the study based on how they used the Interactive White Boards (IWB).

The study used reasonable methods to counter the observer and novelty effects by placing the observer in the classroom for a long period and running the experiment for six weeks. The diverse student population gave the study generalizability to other diverse populations but no specific subgroups. The study controlled for teacher diversity effectively, giving the results generalizability across different teaching methods. The p values for Questions One and Two were less than 0.001, giving the study high validity with the lowest t value being 7.712. For questions Three and Four there was a difference in male and female engagement without the interactive whiteboard (IWB) as high as $F=7.911$ with a p value less than 0.005 while with the interactive whiteboard the F value was 0.417 with a p value of 0.519, showing that with the interactive white board the difference in gender engagement was negligible.

The IWB improved student engagement as self-reported on the survey and in a positive correlation with the observation checklist. Students also showed increased positive classroom behavior with the IWB in use. There was also a gender gap in behavior and engagement without the IWB that disappeared when it was in use. This gender gap was less male engagement and less positive behavior without the use of the IWB. Since the IWB can be incorporated into many content classes the research is applicable across content areas.

Lee and Erdogan (2007) asked what the effect of science-technology-society teaching on students' attitudes toward science and certain aspects of creativity are. This question was addressed through a quantitative study included 14 class sections taught by 7 teachers and made up of 591 students. These students were all taking science classes. The teachers had been trained for 4 weeks at the University of Iowa in how to deliver science curriculum through introducing socio-scientific issues using technology in a problem-based real world (society) context. Before and after the series of lessons students were given surveys, which measured their motivation for learning science. Students were drawn from both high school and middle school levels.

The teacher each was responsible for instructing one control group and one treatment group. They were encouraged to each class authentically, according to the assigned method. The control group was taught using traditional methods, while the treatment group was taught using a Science-Technology-Society (STS) approach. Both groups used the same text book and received the same amount of class time over a four week period. Several Variables were controlled for: Student grades, the same participating teachers, gender distribution, and group size.

Science-Technology-Society (STS) is the teaching and learning of science-technology within a context of human experience (National Science Teachers Association, 1993). It does not dictate a specific teaching model, but focuses on the idea that teaching should be meringue, exciting, and appropriate for students. To facilitate this open ended inquiry or Problem Based Learning are recommended through the use of a question, a problem, and a situation relevant to and appropriate for the students to investigate and develop potential solutions for.

Surveys were given before and after the experimental period of teaching and their results were compared. The surveys were The Attitudes Towards Science Inventory (ASI) and the Assessment of Student Creativity (ASC). The ASI is based on a 5 point Likert scale from 'never' (1 point) to 'always' (5 points) and consists of 18 items. The ASC tracks Questioning, Reasoning, and Predicting Consequences on a three point scale of 'Irrelevant' (0 points), 'Pertinent'(1 point), and 'Unique, (2 points). Inter-rater reliability was found to be 0.91 for the ASC during this study.

Model document, video recordings of the classes, and the classroom materials used for the lessons were collected for further analysis. All instruments used were translated into Korean and then back translated into English by another set of teachers to check the accuracy of the translation.

The program greatly improved student motivation for learning science, with the attitude survey (ASI) resulting in an f value of 15.340 and a p value of 0.008. Students also showed through their projects a level of increased creativity in what they produced, with an f value of 9.504 and a p value of 0.022. Students taught with these approaches showed significant improvement in the development not only of more positive attitudes toward science, but also of their creativity skills. Increased teacher skill likely played a role, but as their skill base was built on technology use this certainly was essential to the outlined approach's success. Students taught using traditional methods showed an overall decline on both tests.

The study was done over a fairly short period. A longer term study would be ideal to confirm long term effects on shifts in attitude and scientific approach. P values were strong despite the short time of experimentation and correspond with similar studies. The use of the same teachers for both control and treatment groups was used for the reasons of internal validity, as well as implementation or implementer bias. This leaves open the possibility of an implementer effect due to the teacher knowing which group is expected to change; this is generally the case in these kinds of studies however and the teachers were asked to implement both traditional and STS approaches authentically.

Liu, Toprac, and Yuen (2009) asked what factors make a multimedia learning environment engaging? This was addressed through a qualitative study of 57 6^{th} grade students (51% female, 49% male) in a suburban Southwestern middle school. Interviews were the primary data source. These interviews were then transcribed and analyzed looking for themes (constant comparative method). The study took place in a medium-sized middle school in a suburban Southwestern community. The researchers had designed the software and teachers were trained to implement it. Although there were 110 sixth graders participating in the study only 57 were interviewed by the researchers. They were chosen at random based on proximity to the researchers in the classroom at an optimum time to do an informal interview during the 3 week PBL unit. Students were also interviewed after the unit in a randomized sample again based on availability of both students and researchers. Both individual and focus group interviews were conducted. Focus groups were randomly formed with between 2 and 5 students in close proximity in the classrooms. Sixty interviews with a total of 57 different student participants were completed using audiotape.

The interviews were open-ended and took place during and after the 3 week PBL unit that integrated software known as *Alien Rescue* a ‘game’ that enhanced the PBL unit. Interviews lasted in length from 5-20 minutes and students were randomly selected from the classes based on availability to the researchers. Interview transcriptions were analyzed first into student response categories and then categories were sorted into themes. Researchers were focused on motivation and emotion of the subjects. Eleven motivation themes emerged through analysis: authenticity, challenge, cognitive engagement, competence, choice, fantasy, identity, interactivity, novelty, sensory engagement and social relations.

Students found authentic learning to be motivating and valuable. They liked the challenge of the software *Alien Rescue*. Students also liked the feeling of being in control of their learning, which they saw as 'fun' because of the interactive nature of *Alien Rescue*. The cognitive engagement was mentioned most in the interviews. Researchers categorized this from the students' discussion of four areas: learning, problem-solving, researching and thinking. The second category of most mention was competence. Researchers also called this confidence/self-efficacy. Students cited their knowledge had increased regarding space, space travel and their roles as 'scientists' were enhanced because of the interactive nature of *Alien Rescue*. Students also liked and were motivated by the unit because of the fantasy nature of *Alien Rescue*. Some students identified with the aliens or their role as scientists in this PBL setting, which the researchers categorized as identify/attainment value. Students cited the activeness, computer-based unit and playing the game as important. Playing became a key theme for the researchers in their conclusion of what motivated the students overall. Novelty was also engaging for the students. Most of their PBL work had not been integrated with technology. The audio and visual portions of the software engaged students.

Researchers categorized this as 'sensory engagement.' The software as well as the PBL format required students to work in collaboration. The researchers categorized this as 'social relations' and discussed the category of 'humans as socializers' as an intrinsic motivator leading to higher student engagement. Motivation overall was summarized in *Alien Rescue* as authenticity, challenge, cognitive engagement and competence. They noted that this confirmed earlier research findings.

The findings around motivation confirmed earlier studies. The researchers plan to build on their findings looking at how to optimize intrinsic motivation using multimedia such as *Alien Rescue*.   They are also looking at developing a rubric for evaluating future research on motivational characteristics using similar software.

The research centered on a computer game which posed a specific problem students could solve within the framework of the game. The solutions were fairly open ended. Interviews were conducted in a semi random fashion, though this probably resulted in a somewhat unconsciously bias sample.

Liu, Hsieh, Cho, and Schallert (2006) asked if students' self-efficacy for learning science, attitude toward science and science achievement change as a result of using a computer-enhanced PBL environment, if there is a relationship between students' science self-efficacy beliefs and their attitude toward science after they engaged in a computer-enhanced PBL environment, and how students' science self-efficacy beliefs and their attitude toward science relate to their science achievement after they engaged in a computer-enhanced PBL environment.

This question was addressed with both qualitative and quantitative methods, with Qualitative data collected and analyzed to confirm the qualitative findings. 549 sixth grade students from a Midwest medium-sized city in two separate middle schools were also included in the study. Both middle schools used PBL as their approach for science. Demographics were 16% Hispanic, 6% African-American, 73% Caucasian and 5% other ethnicities. 75% were regular ed., 15% gifted and talented, and 10% special education students. Five teachers taught these classes.

Alien Rescue, a hypermedia CD-based PBL environment designed for 6^{th} graders as curriculum was used for three weeks daily in their 45-minute science class. Teachers were already familiar with PBL but attended a workshop about integrating PBL and technology.

Data included a science achievement test that assessed scientific knowledge (15 questions) and application (10 questions). Liu used *Alien Rescue* in other studies. This test was used both pre and post the unit to test learning gains. The posttest was given three weeks after the unit to test longer learning.

Self-efficacy was assessed with a questionnaire. There were 8 items given to the students based on a strategies for learning questionnaire first given in 1993. Students rated themselves on statements on a 5-point Likert scale with 1 = 'not being true of me' and 5= 'very true of me.' This same questionnaire was given before and after the unit.

A questionnaire was also used to assess students' attitudes toward science. This questionnaire was also used in past research. It has 14 Likert scale items with 1='strongly disagree' and 5 = 'strongly agree' for each of the 14 statements. In the post-survey the words 'after *Alien Rescue*' was inserted into the more general statements about science. This same questionnaire was given before and after the unit.

Twenty students were also interviewed mid-way through the unit about their *Alien Rescue* experience and what specifically they liked and disliked. The teachers identified these students for the researchers based on the researchers' request for students who both liked and disliked science. Interviews and the open-ended questions were analyzed and coded for patterns and common themes by three researchers working independently of each other. Students were also asked three open-ended questions after the unit. They responded to these in writing.

There was a significant increase in science achievement from the pre to posttest (25 items) with $p<.001$. Students' self-efficacy also increased, although according to the research, it was already somewhat high. The increase was significant with $p<.001$ again. Attitude did not reach a significant level, but the researchers noted students already had a positive attitude toward science on the attitude survey given before the unit. A correlation analysis between attitude toward science and self-efficacy showed a positive relationship with $p<.001$.

A regression analysis examined whether students' self-efficacy beliefs and attitude toward science predicted their achievement in science. The researchers found that self-efficacy was the significant predictor with a $p<.001$. Attitude was not a significant predictor with $p=.19$.

Overall, students gained in science knowledge significantly after their unit using *Alien Rescue*. This confirmed three previous studies that also used this computer-based PBL unit. The researchers generalized that well-designed technology tools can assist learning for middle school students in a PBL setting. Another conclusion was that *Alien Rescue* would be of use to other classes as a way to motivate students where attitudes towards science were not as high as in these five classes. This was based on feedback from students during the interviews. Both quantitative and qualitative data showed that *Alien Rescue* was an effective tool for increasing students' scientific learning, but the lack of a control group demands examination of other, similar studies.

Lambic (2011) asked what effect computer programming lessons which use mathematics have on student enthusiasm for mathematics and interest in studying them in the future. This was addressed in a qualitative study of 114 students between the ages of 13 and 19. Students were drawn from both high school and university levels. They were placed in nine classes of forty-five minutes each that would teach them software and game design concepts based on mathematic principles. Students self-selected into groups of 3-4 within each classroom for the purpose of collaboration during the quarter.

Students were surveyed using 6 specific questions focused on their interest in mathematics and their ability to see the relevance of it to computer programming of computer games. The surveys were given before and after completion of the program (September and December) in order to ascertain if their enthusiasm for mathematics had increased.

The program greatly improved student motivation for learning mathematics. Students also showed through the survey that they understood more clearly the relationship between the mathematics class and the programs they used every day. Students also indicated they were more likely to go into a math-related field of study at the end of the 9 weeks than in the survey taken prior to the course.

Though the raw data provided from the survey shows a change in student attitudes a full statistical analysis was not performed. Further analysis of the data would help assure that the change was statistically significant.

Mathematics was linked with concrete examples in this program and the lessons were flexible enough that they could be incorporated into an existing mathematics course or integrated technology program. This approach of students developing their own resources has potential for other school subjects.

Koszalka, Grabowski, and Younghoon (2001) asked how teachers are using KaAMS and NASA resources, how they are changing their teaching practices over time as a result of using KaAMS and NASA resources, how student levels of interest in pursuing science-related careers are changing over time as a result of using KaAMS, and how the use of the KaAMS products diffuse to the surrounding school system. These questions were addressed in a Qualitative study of 3 middle schools in the same rural Pennsylvania district. Six classrooms were involved, including four 6^{th} grades, one 7^{th} and one 8^{th} grade class. The 8^{th} grade was an honors class. Six different teachers taught these classes with experience from 3 to 23 years. Only half of them had used online web resources for instruction. A total of 144 students were involved, with 82 males and 59 females participating (3 did not indicate gender). 153 parents completed the pre- and post surveys. Most of these parents did not have a job in a science-related field.

KaAMS curriculum, which included online resources from NASA, was used in 6^{th}, 7th and 8^{th} grade classrooms for three to six months depending on the teacher. Teachers received training in how to use the curriculum and the technology online. Data collected included teacher attitudes towards the curriculum and PBL as an instructional model.

Teacher perceptions of how well technology was supported at their schools were also collected through the same online survey as their attitudes. The survey was done twice: once before the start of the study and once at the conclusion of their participation.

Feedback from the post-curriculum survey noted that the materials were flexible (teachers could choose which lessons they wanted to use) and they found a variety of ways to take the suggested lessons and activities and apply them in their individual classrooms. Teachers also noted that this helped them change the way they had been teaching.

The researchers reported that teachers were using more of the resources as they became more familiar with this online approach. Teachers also reported that their attitude towards this approach was more positive as a result of using these resources.

Students were given a published career interest survey three times – pre-study, right after the KaAMS curriculum was completed and one month after the lessons ended. Some students were interviewed by the researchers (random sample) and some participated in a focus group (random sample). Student interest in a career in science significantly increased based on the career interest survey given both immediately after the study and still showed the same effect a month later.

Parents also completed surveys at the beginning and end of the school year to see if their perceptions of their student's science program at the school had changed. These surveys had been used before by these researchers in a similar study.

Observations were conducted several times during the study. This included observing how the materials were used, how students participated in the activities and the resulting artifacts developed by teachers and students (modified or additional lesson plans/ projects by teachers, student products). There was an increase overall in the parents' perception of their child's school as delivering high quality science curriculum and instruction after the use of the KaAMS project. They also saw the use of science resources as increasing.

Only preliminary findings from raw data were reported in this review. The same study was going to be expanded and replicated as part of the next series of testing the NASA-funded KaAMS curriculum integrated with NASA online resources. The same research questions would then be compared to the data collected in this first study and the data would then be compared and analyzed. Overall, the study's use of multiple data points gives the findings strong validity, though one must be aware of the potential motives of the surveyors, as the study was conducted by those providing the resources.

As reviewed in this section, including technology in the classroom has many benefits, particularly as an instructional and engagement tool. As outlined in previous sections, motivation is highly important to student success and learning. Though deeper integration is the focus of this review, Morgan (2008) found that even the inclusion of a single piece of technology had a significant impact; using an interactive white board improved student engagement, positive classroom behavior, and that male students' behavior and engagement improved, eliminating the gender gap in these areas. This simple inclusion is just a small example of the power of including technology in lessons, when combined with a technology based pedagogy the effects can be far greater. Lee and Erdogan (2007) showed that motivation for learning science was greatly improved by delivering science curriculum through introducing socio-scientific issues using technology, showing that this can be an effective method for improving student success and learning. Similarly, Ertmer, Ottenbreit-Leftwich, and York's research (2007) showed that it was a belief in increased student engagement and learning that lead award winning teachers to use technology in their classrooms, showing that teachers were using these techniques for the same reasons that the previously mentioned study found to be effective.

Further, intrinsic motivation can be improved within a technology based PBL environment, as shown by Liu, Hsieh, Cho, and Schallert (2006) as computer-enhanced PBL environments increased self-efficacy for learning science significantly. Feeling competent is important to student engagement, and if this important factor can be significantly enhanced through technology, that alone is worth consideration. Further they found that self-efficacy has a correlation with a positive attitude toward science, and that self-efficacy was a significant predictor for achievement in science. Clearly this technology based PBL can be a powerful tool for achievement in science. This is not a success which is isolated within a single discipline however, as Lambic (2011) found that teaching mathematical concepts through software and game design greatly improved motivation for learning mathematics.

Liu, Toprac, and Yuen (2009) found that a software based PBL tool was effective at engaging students in collaborative problem solving and challenged them intellectually. As collaborative problem solving is a technique that can be used in any school subject, these findings would indicate that this kind of program could be created for many different subjects.

If these techniques were especially difficult to implement or required significant setup time these findings would be interesting but implementing them could be considered impractical. However, Koszalka, Grabowski, and Younghoon (2002) found that teachers considered the materials flexible, used more of the resources as they became more familiar with this online approach, and that their attitude towards this approach was more positive as a result of using these resources. Clearly these are skills which teachers can develop and become engaged with, growing to see as highly valuable. One study in this section touched on combining a Problem Based Learning environment with technology. The following section will go much more into detail about how this is achieved and what the benefits of this approach are.

Technology Skills Provide a Strong Basis for PBL

This section of the review discusses how five studies showed that technology skills provide a strong bases for modern PBL teaching. Walker, Recker, Roberstshaw, Olsen, Leary, et al. (2011) found that a pre-technology approach to incorporating technology and problem based instruction was most effective at assuring that the Problem Based Learning elements would be integrated into classroom practice then when technology skills were taught concurrently with Problem Based Learning projects. Geier, Blumenfeld, Krajcik, Fishman, Soloway, and Clay-Chambers (2008) found that urban student participation in project-based inquiry science curricula embedded with technology lead to demonstrably higher student achievement on statewide assessments over and above general district-wide efforts at reform. The researchers also concluded that the use of PBL units with technology embedded is an effective way to engage urban males at the middle school level. They also noted a cumulative effect on student achievement in science. This study was replicated in 2006 with similar results. Ravitz (2010) found that teachers who indicated the most use of the online features were the same teachers who felt prepared to use PBL enhanced with technology and reported less challenges. Liu, Bera, Corliss, Svinicki, and Beth (2004) found that there was a statistically significant association between cognitive tool use and cognitive processes, the more engagement the students reported the more tools they used, and that there is some empirical evidence in this study that the hypermedia-based tools in *Alien Rescue* play an important role in assisting sixth graders in problem-solving learning. Belland, Glazewski, and Richardson (2010) found that hard scaffolding (technology as a support for the inquiry-based setting) can enhance the students' development of argumentation in Problem Based Learning setting.

Walker, Recker, Roberstshaw, Olsen, Leary, et al. (2011) asked several questions; to what extent do professional development participants design activities using the Instructional Assistant (IA) search engine and online web designer and then use them in the classroom? To what extent do professional development participants show changes in their knowledge, experience, and confidence in technology integration in teaching? To what extent do professional development participants use PBL in their IA projects? How do professional development participants describe their technology integration and use of PBL in the classroom?

A mixed-method approach was used to address these questions. The first three of the questions were addressed with quantitative research and the final question used a qualitative case study using a sample from the larger group of teachers (6) who had early, middle and many years in the classroom (2 each). They were offered one college credit for their completion of a series of workshops integrating technology with PBL with the goals of using the IA online tools in their classroom along with PBL instruction. The first group had a 22% drop-out rate and the second lost 30% of the teachers. Researchers mentioned severe budget cuts in the district as a possible reason for this.

The two groups were each part of a separate enactment. This was done to compare two professional development approaches using PBL and technology.

Enactment one and two participants were both provided with 90 minutes of technology instruction and 120 minutes of PBL instruction. However, group two (tech first, then PBL) the participants had one more formal workshop to do their projects. The same data points were used in each enactment. Both enactments used pre and post-surveys for participant knowledge, experience and confidence using technology, then looked at the online login data (IA web projects), the number of projects completed, number of projects used by students (login data) and number of visits per IA projects once online. For the case study, the 6 participants wrote reflective papers sharing their personal perceptions of how comfortable they were with their technology knowledge, their use of the IA tool and their perception of how they were using both in their respective classrooms. Three were from the PBL integrated with technology group and three from the technology instruction prior to PBL group.

The researchers found that the tech-prior participants designed about the same number of projects as the tech-concurrent group. Both groups had a high number of visits per project indicating student use but the tech-prior group had a significantly larger number of visits overall. Survey results for participant knowledge, experience, and confidence using technology were statistically the same for both groups. The final quantitative question dealt with the alignment of IA projects with PBL. The researchers found the elements of PBL in the projects (a rubric was used to score this) for the group who had PBL and tech delivered together were low for the entire group. The tech before PBL group had a much higher score on the rubric for PBL elements in their projects.

The qualitative portion (case study) found that with the three participants from the tech-PBL integration group the reflective papers discussed their technology use and comfort increased far more than did their PBL integration into classroom practice. The most experienced teacher in this group noted she had not incorporated PBL at all into her classroom at the time she wrote the paper. However, the tech before PBL instruction group focused far more on their PBL instruction now becoming part of classroom practice than it had been in the past. The conclusion was that participants in the tech-concurrent PBL enactment had a more in-depth and broader use of technology than PBL methodologies. The tech prior to PBL group self-reported and the quantitative data also showed that elements of PBL instruction were present at a higher level with this group. The quantitative and qualitative research findings paralleled each other in the results. The researchers plan to explore these findings in future professional development with teachers using the tech prior to PBL approach as well as planning to examine the impact on students when engaging them in PBL activities with online resources.

Geier, Blumenfeld, Krajcik, Fishman, Soloway, and Clay-Chambers (2008) asked if urban student participation in project-based inquiry science curricula embedded with technology lead to demonstrably higher student achievement on statewide assessments over and above general district-wide efforts at reform, if there a difference between male and female student achievement using this same approach, and if there is difference between grade levels using this same approach. These questions were addressed in a quantitative Correlational cohort study.

This Michigan urban school study was three years in length (1997-2001 school years). It used a PBL series of units eight to ten weeks in length. 37 teachers participated in the study in 18 schools with a total of 5,000 students who participated in two 7^{th} grade and/or one 8^{th} grade unit of the LeTUS science curriculum. Two cohorts were followed. The first cohort was smaller than the second. The second cohort also had more schools and teachers participating to see if this model could be scaled up.

This curriculum was scaffolded with technology tools matching the science curriculum including data probes, and software packages to support novice technology learners in their inquiry-based science class. Software expanded students' range of questions to ask and new ways to measure and display data.

Prior to the study teachers were trained in how to use the LeTUS curriculum with embedded technology software during a week-long summer class. They also participated in monthly workshops and discussion groups. They had online support and limited support from the graduate student researchers. Over the three years the professional development was adjusted to fit the needs of the teachers based on feedback. Both technology and PBL methods were addressed.

The measure used was the Michigan Educational Assessment Program (MEAP) test for science given in grades 5, 8, and 10. Since the students were in grades 7 and 8, the assessment used was the 8^{th} grade test, given in late January of the 8^{th} grade year.

The test measures three content areas: life, physical and Earth science. It also tested the process skills of: constructing and reflecting. The LeTUS science curriculum units covered all of these areas. The test scores show an overall science score as well as student proficiency categories of "not yet novice" (not passing), "novice" and "proficient."

There was no multi-year analysis because the test did not have between-year test reliability according to the researchers. Each year of the three years was examined individually with results of participating students compared to the group who did not use the LeTUS curriculum and technology but did use an inquiry-based reform model science curriculum that was not technology-enhanced. Students did not have to participate in all three units (two in seventh, one in eighth) to be part of the study. When they were not in these units they still were in a science class that used inquiry-based instruction. However, the researchers did disaggregate and compare gender differences and participation by grade levels, though some students did not complete both years' units.

An examination of each cohort of students showed that the cohorts that participated in the study had significantly higher achievement on the MEAP than the students who did not participate ($p<.001$). Higher scores were obtained in all three science content areas as well as in the two process areas. Even students who only participated in one unit over the two years had an aggregate gain of 14% overall. An examination of the pass rate (above "not yet a novice") on the MEAP showed that students in Cohort 1 had pass rate of 19% higher than their non-participating peers and in Cohort 2 they exceeded them by 14%. Physical science was the most challenging for students to pass and the researchers noted the teachers reporting that it was the most difficult unit for them to teach which may have contributed to the results. The unit has been revised. The researchers noted that the positive results may influence how science is taught throughout the district in the future.

There were statistically different results between boys and girls on the MEAP science test overall in the Detroit Public Schools with boys scoring 17 points below girls in 2000 and 13 points below them in 2001. It was of interest to the researchers to see of the use of the PBL model with technology embedded would make a difference since this was a trend overall in achievement in the district. The findings were that in Cohort 1 there was not a significant difference but in Cohort 2 boys made significant gains in their achievement to close the gap with p>.005. The researchers concluded that the use of PBL units with technology embedded is an effective way to engage urban males at the middle school level.

There was no significant difference in participation by grade levels when disaggregated and analyzed individually. However, when the researchers compared the students who had participated both in seventh and eighth grade years versus those who had only participated one year there was a significant difference with p>.001.

The study was not exactly replicated from Cohort 1 to Cohort 2. The researchers monitored and adjusted the curriculum and staff development based on feedback from teachers. The researchers concluded that the use of technology embedded PBL units has an independent and cumulative effect on student achievement in science. This study was replicated in 2006 with similar results.

Ravitz (2010) asked what the prevalence of PBL use, preparedness, and challenges are, what the prevalence of online feature use to support PBL is and to what extent online feature use relates to preparedness, challenges and use of PBL. These questions were addressed in a quantitative study of 331 teachers representing the four main content areas of math, science, social studies and English at the high school level. These teachers represented 61 large comprehensive high schools, 104 small schools or small learning communities, and 166 represented educational reform models. These reform models were *New Tech High, High Tech High, Edvision*, and *Invision Schools*.

The study began with a request to complete an online survey that was sent to 1200 teachers. The teachers were identified from publishers of PBL materials. Four hundred teachers responded to the survey. Of this number 331 were selected for the study. All of them had used PBL online sites or software as part of this instruction in their classes.

There were five questions that specifically related to challenges the teachers identified when using technology as part of PBL. These were scored on a 4-point scale with 1= not a challenge to 4=a major challenge. Nine items related to teacher preparedness to use PBL. A four-point scale also measured these responses. With 1=not at all prepared to 4=very well prepared. Researchers also looked at the kind and size of schools that were represented to see if there were differences between small schools, small learning communities in large sites and large comprehensive high schools.

Also included in the survey was a list of types of projects and a PBL definition. Teachers were asked to identify which subject they used PBL the most in. They were also asked the percentage of time they spent using PBL as a teaching method using a 6-point scale for responding. 1= almost no time through 6=all or almost all of the time. They were also provided with a list of seven online features divided into planning and implementation tools that could enhance PBL such as a collection of projects from which to choose to tools that helped manage projects online to tools that linked students to outside mentors or experts. The teachers could select all or none of these tools as part of the survey.

Based on the survey results and analysis the research showed that the teachers who indicated the most use of the online features were the same teachers who felt prepared to use PBL enhanced with technology and reported less challenges. The teachers who indicated they felt less prepared were the ones who did not use many of the features they also indicated they had more challenges. The correlation overall was $<.05$. When schools were separated based on their size and type the survey results indicated that 83% of the reform network teachers spent more than 25% of their time using PBL for instruction. In the small schools 48% spent 25% or more in a PBL model and in the larger schools only 34% reported this.

As far as preparedness the results for the different types of schools followed the use pattern indicated in the overall results. The reform network used PBL the most and reported they felt most prepared. The larger schools teachers indicated they felt least prepared with the small schools reporting the same as the reform network group with both indicating that about 83% felt well prepared. The same was true for challenges. Reform network teachers had the least challenges and large schools staff the most.

The reform network indicated the highest use of the online features. 56% had students post project work online, for example. 21% of the small schools and 18% of the large schools indicated they had done this. 58% of the reform network teachers had designed and managed projects online where only 36% of the small school staff had done this and 31% of the large schools teachers had done so. Other feature use had the same order of results.

Use of online features was positively related to preparedness. The more prepared the teachers indicated they were the more of the online tools they indicated they used. Regarding challenges, in all the schools there was mention of the need for more professional development. This varied from 8% in the reform network and small schools to 18% in the large schools. The challenge that was mentioned most often was using the tools that were supposed to help students manage their projects online.

Subjects were analyzed individually to see if there were differences between PBL use, preparedness and challenges. Science teacher results showed that when online features were used there was a decrease in challenges and an increase in preparedness. In social studies, there was a strong relationship between online feature use and the amount of PBL time spent in the classroom. $P<.001$. For English, those who used the online features felt more prepared. $P<.01$. Math teachers reported the least PBL use of all the content areas. However, there was a strong correlation between online feature use and PBL use here as well with $p>.001$.

The study was a self-selecting survey which mainly covered the practices of non-traditional schools. The P values were fairly low, some extremely and selection methods would be a potential area of criticism, more so than data analysis.

Liu, Bera, Corliss, Svinicki, and Beth (2004) asked which cognitive tools are used for which cognitive processes, if there is a relationship between the extent of engagement in cognitive processing by the students and their cognitive tool use, if there are any differences in cognitive tool use and performance scores between students who are engaged in different patterns of cognitive processing. These questions were addressed with a Quasi-experimental research design.

The subjects consisted of 161 sixth graders in six intact classes from two middle schools in the same school district in a mid-sized southwestern city. Demographics of the students were 15% Hispanic, 6% African American, 73% Caucasian and 6% other backgrounds. Three sixth grade teachers participated. Two had worked with the hypermedia program (*Alien Rescue*) before and one teacher had not. The three teachers participated in a workshop that covered the philosophy and characteristics of PBL environments and emphasized the role of teacher as mentor. Teachers reported that the students were all comfortable with computers and had used games and word processing in the past. The three teachers' instructional model was student-centered.

The teachers then spent three weeks daily in their 45-minute science class with students addressing the problem of aliens who had been displaced from their six planets needing new homes that met their life-sustaining requirements. This problem was presented in *Alien Rescue*. Students worked in groups of 4-5 using the 13 tools provided in the software.

Researchers grouped the 13 tools into 3 groups: 1) tools that supported cognitive load, (4 databases in *Alien Rescue*) 2) tools that supported activities otherwise not possible, (probes, i.e. thermometers, in *Alien Rescue*) 3) tools that supported hypothesis testing (i.e., the 'expert helper' in *Alien Rescue*). Students provided feedback on which tools worked best for them on the 20-item cognitive task questionnaire at the end of the unit. The questionnaire had been designed by having doctoral students (3) play *Alien Rescue* and list the most common processes they used to solve the problem. The top 20 steps were then compiled into the questionnaire. The answers were on a Likert scale with 1=not at all and 5=all the time when referring to the questions about the processes they used.

At the end of the unit students presented their solutions to where the aliens should live in a formal presentation setting. Teachers observed as facilitators all stages and through interviews provided feedback on the students' tool use and their solutions to the *Alien Rescue* problem of relocating the aliens. Students then took the same science knowledge test given at the beginning of the unit. Results were compared to the pre-test.

The researchers examined the relationship between the 3 categories of cognitive tool use and the four categories of cognitive processes. A statistically significant association was found between the two (p=<.01). They used a Chi Square analysis. The relationships most significant were between: tools that support the cognitive load (search engines in *Alien Rescue*) and all four cognitive processes (understanding the problem, integrating information, evaluating the process and outcomes and identifying, gathering and organizing important information). For the tools that support activities otherwise not possible (use of the probes in *Alien Rescue*) students reported higher than expected frequency of use for the 'identifying, gathering and organizing' process. Strong associations were found between tools that support hypothesis testing and the process of integrating information.

To examine the link between engagement in cognitive processing by the students and their cognitive tool use these researchers did a correlation analysis between students' reported engagement level and their reported tool use on the questionnaire. This showed that six of the 20 statements had a statistically significant moderate positive relationship between the students' reported engagement level and the frequency of tool use in all four categories. The more engagement the students reported the more tools they used.

The questionnaire was also used it examine the differences in cognitive tool use and performance scores between students who are engaged in different patterns of cognitive processing. A factor analysis was conducted. Two factors were identified. One was information processing and the other metacognitive. They then assigned students to one of the two categories. Informational students reported themselves as 'action-oriented.' The metacognitive group saw themselves as more thoughtful, problem-solvers. When researchers analyzed the students' reported use of the number of types of tools used there was no significant difference. However, when they looked metacognitive group they discovered that they reported more consistent use of certain tools and the informational group reported a higher degree of engagement in the 20 different cognitive processes. Researchers then looked at performance scores to see if there was a difference between the metacognitive group and the informational group on either the pretest or posttest. There was no significant difference. However, when they examined pretest and posttest results for the entire six classes they found that there was a statistically significant difference (p=<.01).

Different types of tools were used for different types of processes and connections were found between cognitive tool use and cognitive processes. There is some empirical evidence in this study that the hypermedia-based tools in *Alien Rescue* play an important role in assisting sixth graders in problem-solving learning.

Despite the lack of a control group, the p values (p=<.01) are worth consideration that the findings of the study are based on good data and the conclusions drawn from the qualitative analysis also seem based in quality observation and interviews.

In addition, the questionnaires were created by experts in the field who were doctoral students with experience with the research tool (*Alien Rescue)* as well. The cognitive processes they used to create the Cognitive Task Questionnaire were at rigorous standards for the grade six students with four conceptual categories for the items on the questionnaire. These had been categorized by two experts in cognition. There were 20 activities in the questionnaire and the three teachers reviewed the items for clarity and appropriateness for sixth graders.

The questionnaire design was based on well-accepted practices in the field. The flaw in the questionnaire results is that they are self-reported data that is not correlated with observational data which would strengthen both the survey results as well as the study overall. Statistical analysis was sound as a 5-point Likert Scale was used for the 20 items.

Additional analysis looked at the completion of the science knowledge test after the unit. This was the dependent variable with the pretest used as the covariate. The students had been divided into two cognitive groups based on their questionnaires which indicated their frequency use of the tool based on 20 items regarding its use. These groups were both problem-solvers but group one was metacognitive in their approach and group two was more action-oriented in how they interacted with *Alien Rescue*. The performance for both groups significantly improved between the pretest and posttest for both groups with $t=24.49$, $p<.01$.

One final note is that teachers were chosen for their instructional style which matched the use of the tool, *Alien Rescue.* Researchers concluded that different cognitive tools are used for different processes and student engagement is related to the use of tools they used frequently. They also noted a weakness in the study could be that the students reported what they thought their teacher wanted to see on the questionnaire and since there were only three teachers the study needs to be replicated and correlated with observations.

Belland, Glazewski, and Richardson (2010) asked what the impact of hard scaffolds on argument evaluation ability during a PBL unit is, what the impact of hard scaffolds on argument quality during a PBL unit is, and how and why do middle school science students use hard scaffolds to construct an argument while participating in a PBL unit.

A mixed method design was used to address the different question types. Quantitative methods were used on the first two questions, those addressing argument evaluation and quality. Case study qualitative methodology was used to answer the question which addressed using hard scaffolds to construct an argument while participating in a PBL unit, which used a ‘two-factor nested experiment’ (small groups were nested in the larger classrooms used for the qualitative research setting). The independent variable was the hard scaffold, the *Connection Log*, a web-based tool developed by the researchers to support the students while constructing and presenting their arguments during a PBL unit.

One teacher was identified to participate in this research due to her four year experience with PBL. Four of her 7th grade classes sections participated, two of which were control groups and while two were treatment groups. 86 students participated in total, with 41 in the experimental group, of which 15 were in the higher- achieving class and 26 were in the lower-achieving class. 45 were in the control group, with 22 in the higher- achieving class and 23 were in the lower-achieving class. Within the two experimental groups were two small groups of students selected for the qualitative research. 3 were in the lower-achieving class and 2 (later a 3rd was added) to the higher-achieving group.

The high and low achieving students were identified by standardized test scores, grades and teacher perception. Videos with transcriptions resulted in rubrics designed and used to quantify the areas to be measured: argument quality (included evidence for support), argument construction (included presentation) and the connection between construction and quality. Forty-five minute interviews were also conducted with the small groups as part of the qualitative research. 20 minutes of video were shown to the students during these interviews to get their reaction to their classroom interactions, on-task participation, and feedback on use of the Connection Log (hard scaffold). Informal interviews were also used.

Hard scaffolds had a significant main effect on the argument evaluation ability of the lower-achieving students. This was twice the effect on all four classes collectively. The researchers concluded that a system of hard scaffolds (in this case the web-based tool that guided PBL process) had the potential to help lower-achieving students during PBL units. Specifically, in this research, to help middle school students critically evaluate support for a claim.

The higher achieving group scored better on argument quality when it came to stating their claim, but were weaker on evidence to back up that claim when using hard scaffolds. They actually scored lower than their matching control group, as they ran out of time during the persuasive evidence portion of their presentation.

As mentioned, qualitative methods were used to address how and why middle school science students use hard scaffolds to construct an argument while participating in a PBL unit. The case studies indicated that the Connection Log from the students' view helped them look for more relevant information, create an argument based on this information, and work as a team to construct an effective argument and presentation.

Researchers also noted from observations that the experimental groups delegated responsibility more often that the control groups using the hard scaffolding of the Connection Log. The students used this computer-based tool to write down information and to guide the processes throughout the PBL unit. The control groups were both observed looking for the same information several times noting when asked by researchers that they had failed to write it down or lost the paper from the previous days' work.

The use of the mixed-method design gave the researchers more ways of looking at test subjects and strengthened conclusions since both methods were used concurrently at all stages. In addition, the inclusion of both high and low achieving experimental and control groups gives the study more validity. These groups were examined using both quantitative and qualitative methods and the results supported each other's conclusions. The quantitative conclusions were significant for both high and low achieving groups with $p<.01$ and with an f value of 8.16.

Since all classes were taught by the same teacher, all received the same level of expertise. Instructionally, the teacher had four years of Problem Based Learning experience and a Masters in Education. However, since there was only the one teacher, there was no control for how well she implemented the experimental procedures.

The materials used were assessed for readability using students outside of the study subjects (they were not in the experimental or control group). Some of the students were noted as high academic achievers as part of their participation in the readability of the materials results. However, the rest of the students who participated in the readability assessment were not disaggregated by academic ability so there was no way to know if the materials were sufficiently accessible to those who were the lower achieving students in the actual study.

There was a large amount of data collected for the qualitative portion of the study. All groups were videotaped, the dialogue was transcribed and information from student logs was collected. In addition, follow-up interviews with the students were conducted and these included replaying video clips for the students to refresh their memories of the actual PBL work. Classroom observations were also done. This large collection of qualitative data gives credence to the quantitative data and supports its results.

Due to inequalities of variances, nested MANCOVAs were used to measure the differences in arguments in the evaluation scores. Positive results were addressed with follow-up ANOVAs. This should have avoided any false positives. However, it may have resulted in negatives as negative results were not given any follow-up analysis. This could be done in another study. Statistically, providing hard scaffolding (concrete support through a *Connection Log*) on argument evaluation ability in PBL had a result with $f=2.99$ and $p= 0.09$. This is worthy of note in that students in the experimental group had higher posttest scores than those who were in the control group with no hard scaffolding for their inquiry-based work. For a nested effect on the performance of the lower achieving students there was a statistically significant result with $f= 6.07$ and $p = 0.01$, the conclusion being that these methods were more effective for lower achieving students. The researchers also looked at the impact of hard scaffolds on argument quality in an inquiry-based approach but found no significance there.

Overall, the research looked for patterns and common themes in all areas: video, interviews and classroom observations to triangulate their research. Based on the data, the researchers concluded that hard scaffolding can support students' development of argumentation in an inquiry-based setting. Future research will include continued use of the Connection Log as well as other hard scaffolds as opposed to mentors. It will also include more teachers and a larger sample for the qualitative portion of the study, and will include different schools and students.

As discussed in the studies above, technology and Problem Based Learning works well when combined. Both effectively to motivate students and technology can be used to support otherwise complicated or time consuming aspects of PBL. When implementing these it is best to focus on teaching both skills simultaneously (Walker, Recker, Roberstshaw, Olsen, Leary, et al., 2011). This allows for smooth integration of the two. As shown by Ravitz (2010), teachers who used online features were more prepared when it came time to engage students in tech based PBL, which shows that the more technology integrated the classroom the more efficiently a teacher can engage in these techniques.

A key component of Problem Based Learning is critical thinking and the development of argumentation, which Belland, Glazewski, and Richardson (2010) showed can be effectively supported through hard scaffolding via a computer based tool. Similarly to Morgan (2008), Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, and Kocaman's (2009) findings showed that integrating technology into PBL increases the engagement of male students without negatively impacting the engagement of female students. As motivation is such an important component to learning this further reinforces the benefits of integrating PBL and technology.

Liu, Bera, Corliss, Svinicki, and Beth (2004) found some empirical evidence that hypermedia-based tools play an important role in assisting sixth graders in problem-solving learning. The more engagement the students reported the more tools they used. With this correlation in mind it can be seen how the key components of PBL can be made easier for students to engage in through technology based tools. With the importance of engagement as outlined earlier in this review, it is worth considering how these tools can improve student learning.

PBL is More Effective than Traditional Methods for Skill-based Learning

Five studies in this review showed how PBL is effective at long term learning and building up skills, particularly when compared to traditional, lecture based instruction. Wirkala and Kuhn (2011) found that both individual and group PBL is more affective for long-term learning than lecture discussion. Mergendoller, Maxwell, and Bellisimo (2006) found that PBL was a more effective delivery method for content than traditional instruction and that verbal ability did not play a significant role in success with PBL.

Guiterrez-Perez and Pirrami (2011) found that students felt they learned better with PBL than through lectures, and that teachers found PBL methods preferable to lecture methods. Liu (2004) found that students had a statistically significant increase in scientific knowledge. Yew, Chong, and Schmidt (2011) found that learning was cumulative in PBL, that certain steps on PBL are more important to learning than others, that acquisition and elaboration of concepts was significant in both the self-directed phase and the reporting phase, and that the listing of concepts and counting repeated concepts may be a valid way to quantify learning in the PBL process for large groups.

Wirkala and Kuhn (2011) asked if PBL produces superior results to lecture/discussion in a K-12 setting and does a PBL-team approach produce superior results to a PBL-individual approach in a K-12 setting? These questions were addressed through a quantitative study of three classrooms made up of 90 total students and a control group of 94 students. All classes were equally diverse with equal proportions of Caucasian, African American and Hispanic students. Free and reduced lunch was 60%. No special education students attend the school. Students were instructed in the spring of their 6th grade year and again in the fall of grade 7.

The instructors covered two topics and were assisted by researchers acting as coaches: 1) Groupthink, a letter-based NASA problem related to the Columbia disaster. This centered on the team's decision-making, not the actual cause of the disaster, 2) Memory, another letter-based problem presented around whether medical interns are able to make good decisions based on their study habits. The letter addressed a case where the incorrect limb was amputated. However, the topic for the 6th grade students was about how memory is affected by rest and accessing prior knowledge.

Each topic was done in 30-40 minute class sessions over 1.5 weeks for a total of 2 hours for each topic. Assessment was done 9 weeks after the original classroom instruction with summer vacation in the middle. Students were in the fall of their 7th grade year during the assessments. Comparisons were made between the PBL team group and the PBL- individual group. Comparisons were also done between the lecture/discussion group and the PBL groups collapsed together. This was possible based on the similarity of the assessment results between the two PBL groups. Statistical significance was set at .05 alpha level.

The PBL groups had three adults facilitating their work: the two researchers as coaches along with the regular classroom teacher. The lecture/discussion approach used the two researchers. One was the lecturer and the other the facilitator of behavior and helper with the discussion facilitation. Assessments included both comprehension and application to a new context. The assessments took a single period. Long-term, enduring learning was the target. Assessment was done 9 weeks after the original classroom instruction with summer vacation in the middle.

Assessments included an assessment of comprehension and application to a new context. For Groupthink this context was a team of diplomats who had to plan an approach for meeting with Iran regarding nuclear disarmament negotiations and for memory it involved an international reporter who could not carry his notes out of a war zone and had to commit the notes to memory for his article back home.

The assessments took a single period and also included definition of terms that students had been given on a planning sheet in both the lecture/discussion group and the two PBL settings (this was the scaffold in the first session, but the sheets were turned back to the coaches). Both of these forms of assessment were used to answer the research questions. Long-term, enduring learning was the target.

The two PBL groups had similar results on the Groupthink comprehension assessment related to definition of concepts ($p=.050$). However, the PBL groups combined had a significantly higher number of concepts defined than the lecture/discussion group ($p=.001$). The explanation portion of the assessment show similar results with the two PBL groups but when compared to the lecture/discussion group the PBL group reached the explanation level but the lecture/discussion group did not ($p=.006$). The majority of the lecture/discussion students scored 0 or 1 on the explanation rubric. The shorter term of the studies allowed tighter control over the instructional methods used. The findings had a high level of statistical significance between the control and experimental groups. The use of instructional aides and teacher quality likely had an effect that is not accounted for.

Mergendoller, Maxwell, and Bellisimo (2006) asked whether there are differences in achievement, as measured via pretest-posttest changes in macroeconomics knowledge between students in PBL and traditional instructional environments as well as looking at the difference in achievement as measured via pretest-posttest changes in macroeconomics knowledge, between students with different levels of verbal ability in PBL and traditional classes, and whether there is a difference in achievement in a PBL versus traditional classroom instructional model as measured among students with different levels of interest in learning economics, preference for group work or problem-solving. These questions were addressed in a Quantitative “Black box” design that included no classroom observations.

The study spanned a two-week unit in macroeconomics during the second semester of the students’ senior year. This was a one-semester course with classes taught by 5 veteran high school economics teachers in four schools. 346 high school seniors attended a semester-long macroeconomics course spread into 11 different classrooms through 4 schools in two different districts in a northern California metropolitan area. 246 students completed the study. High absenteeism was due to the fact this was the students’ last semester of their senior year according to the researchers and the teachers. Absences mirrored other classes of seniors in the schools. The five participating teachers had been part of a one week PBL workshop the prior summer. The content concepts for the unit selected for the study was the same in both the traditional and PBL classrooms. The teachers used a pre-packaged PBL unit that was the same in all the PBL classrooms. Traditional classrooms used the same California adopted text that was based on the economic standards for the state. One traditional section was taught by each of the five teachers. PBL sections varied based on the number of macroeconomics classes assigned to each teacher. One of the five taught one PBL, three taught two other sections and one had three PBL sections.

Whether there are differences in achievement, as measured via pretest-posttest changes in macroeconomics knowledge, between students in PBL and traditional instructional environments was examined by collecting data from a 16 four-part multiple-choice question test taken from a macroeconomics text using only questions covering the content and concepts in the classrooms. Results of this test were then analyzed for all 11 classes by first summing up the scores of the correct answers for each of the classrooms before and after the unit. Comparisons were made between before and after the unit for all students who were present for the entire two weeks. The data was then examined between those in the PBL delivery classrooms and those in the traditional classroom settings.

The researchers found that there was a statistically significant difference between the average pretest-posttest score in content/concept knowledge when comparing the PBL participants to those in the traditional classrooms ($p=.05$). The researchers also looked at each teacher individually and compared their classrooms (PBL to traditional). Four out of five teachers had larger gains in their PBL classes than their traditional lecture model classrooms. One teacher had the reverse results. That teacher was in the same school as one of the other teachers (the only school with two participating teachers). The researchers concluded that PBL was more effective as a delivery model than was the traditional method based on their $p=.05$ as a level for statistical significance.

To see if there is a difference in achievement as measured via pretest-posttest changes in macroeconomics knowledge, between students with different levels of verbal ability in PBL and traditional classes the researchers once again looked at the data from the 16 four part multiple-choice question test taken from a macroeconomics text using only questions covering the content and concepts in the classrooms. Again, they also looked at correct answers but this time they split the students into three levels of ability for each of the 11 classrooms based on the Quick Word Test, Level 1. (Based on the assessment they designated the ability groups as 'low, medium and high') They then compared the data from the PBL versus traditional classrooms to see if there was a significant difference between the two instructional methods when addressing the same content/concepts for each of the three ability groups first in the individual classes and then as they compared across the two methods (PBL and traditional) for each of the three ability groups of low, medium and high.

The data analysis did not show any difference between the two models when the students were split into ability levels (3 levels per each of the 11 classes) and their pre- and posttests of content/concept knowledge were compared by these groupings in the PBL classes versus the traditional instruction classes. This confirmed the researchers' hypothesis that there would be no difference.

To find if there is a difference in achievement in a PBL versus traditional classroom instructional model as measured among students with different levels of interest in learning economics, preference for group work, or problem-solving efficacy the researchers used their own assessments for looking at interest in economics, preference for group work and problem-solving efficacy.

The interest in macroeconomics assessment was developed by the researchers. Two question stems, one dealing with current issues in economics and one with economic concepts were given. Four possible responses were attached to one stem and two to the other with responses scored on a 5-point scale. The score for each student reflected the mean of the four items.

The preference for group work assessment was also developed by the researchers. One stem was given with four item statements about group work preferences given below the stem. The students scored the items based on a 5-point scale from (1) strongly agree to (5) strongly disagree. The score for each student reflected the mean of the four items.

The third area, problem-solving efficacy, was also measured by the researchers' own assessment tool. This included one question stem followed by 5 item responses for student selection that were scored on a 5-point scale. The score for each student reflected the mean of the five items.

The results here showed that for interest in learning economics, students who had scored in the highest aptitude group also had the highest score on the assessment for learning economics $p<.05$. There was no other statistical significance for either other ability groups or a difference between the PBL and traditional classes when it came to an interest in learning economics. Researchers also noted that traditional students who indicated they had little interest in learning economics had the least change in content/concept knowledge scores on the pre- posttests when looking at individual results. There was also no statistical difference between the two models when looking at students' preference for group work or problem-solving efficacy.

The researchers went on to discuss their findings noting that all three ability groupings did learn more in the PBL setting even though it was not to the level of statistical significance. They went on to state that this would be important to students because it would make a difference in their grade in the class. Another interesting note was that the teacher whose students did better in the traditional classroom had a higher socio-economic group of students than any of the other teachers in the study. The researchers noted this might be worth more study.

Finally, the researchers concluded that PBL is an approach that 'does no harm' and some good at the high school level based on this study. They recommend more studies be conducted at the secondary level.

The data gathering was done entirely through paper work, which allowed for statistical data but failed to address how the teachers were using the lessons, which may be one of the reasons for one teacher's results which were quite different even though teachers were given equal training and taught a two-week PBL lesson, so their skill levels with PBL should have been fairly equal. Teacher sample size was small but student sample size was fairly large and given that teachers had similar levels of skill with PBL.

The study was controlled for teacher capability through a one week training and also by having each teacher teach one control class as well as PBL classes. All teachers had access to the same resources even though they did not all teach in the same school. The pretest/posttest was a test of content knowledge given to all students in both the PBL and traditional setting. A word test was given to assess general academic ability, which has a good correlation with academic ability. However, this could be interpreted as less strong a correlation than if it had been a direct test of academic ability. The researchers also had developed their own instrument for measuring students' self-perception of preference for PBL over a traditional classroom setting. Using this without correlating it to classroom observations (not done) could be a weakness in the study as well as the fact that the instrument was a new design and not an established one.

The challenge of random student selection was partially met as teachers selected their content and class assignments including those in the study at the time they agreed to participate but students were assigned to their classrooms at random within their schools. The loss of 100 students (seniors) during the course of the semester could also be a weakness in the study's results. The researchers compensated for this by substituting the mean score on of the aptitude assessments where student scores were missing.

Conclusions reached were based on a strong statistical significance with a pretest to posttest difference of scores in content knowledge showing that students who were in the PBL classes had an average posttest change of +1.48 and those in the traditional classes an average change of .82. Thus the $t = 1.94$ and the $p = .05$ or an effect size of .59 for those in the PBL classes versus .29 effect for the traditional classes. Researchers also looked for a statistically significant difference among the different student groups based on their overall academic ability as measured by the verbal (word) assessment. There was no statistical difference of significance among these groups. Overall, however, the statically significant results of PBL over traditional instruction can be taken as a strong display of their potential.

Guiterrez-Perez and Pirrami (2011) asked if ICP/PBL would be appreciated by students and teachers, what might be the best way to introduce a curricular topic starting from an environmental issue at the secondary school level and what might be the best way to develop the teaching/learning module with the PBL approach to increasing students' interest and engagement during secondary science lessons. These questions were addressed in a qualitative study of 104 students ages 14-15, who attended six different technical secondary schools in Italy. These students were in pre-existing in-tact classes taught by 6 teachers, none of which had PBL experience but were willing to participate in the study, and 2 researchers, one from Barcelona, Spain and one from Camerino, Italy, who acted as tutors in the classroom. The study included dedicating two hours in four weeks to an integrated PBL unit using an environmental scenario.

The researchers divided the classes into two cohorts. As stated previously, the researchers acted as tutors in the class as well as observers and in C1 they taught the concepts to the class. Both cohorts of three classes each spent four 30 minute class sessions on the PBL unit. They also did research on the concepts outside of class. Students in both groups identified concepts and created a booklet on how and why to conserve water in a village that had frequent water shortages. Cohort 1 had a more traditional approach while Cohort 2 used a more typical PBL approach although both cohorts finished the unit with a lecture by their teacher on the concepts in the unit so that they were prepared for the test.

In Cohort 1 each student was given a text with the environmental real world problem scenario followed by a reading that contained experts' viewpoints on how to deal with the issue in the scenario. The concepts were also outlined in the reading. New vocabulary was identified and defined. There was a discussion about the reading led by the researcher/tutor and concepts were listed on the board. Students were split into groups of 3-4 and given concepts to research further. Students then shared information found on these concepts at the next class. This was repeated three times. After these three classes, a final session was held where the teacher summarized the entire unit to help students prepare for a test.

Cohort 2 (C2) which consisted of the other three classes was given the scenario only. Students were given time to reflect on this individually and told to write down concepts they thought were important to solve the problem. At the next session, a whole-class discussion took place. The concepts were listed and each student was instructed to search for information about all the concepts. In the third session they shared what they had found in small groups. The groups then shared out at the class level. As with C1, a final session was held where the teacher summarized the entire unit to help students prepare for a test.

Researchers recorded the concepts considered by the students as important for both cohorts. They also had observed the students' discussions and had recorded observations about those as well. At the end of the process, teachers were interviewed to learn their impressions of the process in which they participated and finally, the researchers gave questionnaires to the students to assess their views on this PBL approach. The questionnaires contained both multiple choice and open-ended questions (these were analyzed and grouped into categories matching the concepts).

Students reported that PBL as a method for learning was better than traditional learning in Cohort 2 for 56.8% of the group. Cohort 1 was also asked this question, although their scenario was presented in a more traditional way. 52.3% reported they thought they had learned better than the usual lecture model. Students noted in both cohorts (from the open-ended questions) that the disliked that this unit only lasted a few weeks. This was the highest negative response with 19.2% indicating the unit was too short. Secondly, 12.5% reported there was too much homework and the third least liked portion of the unit was that it was not clear what they had to study for the test until the end of the unit, with 10.6% noting this. For this portion, the cohorts were not separated.

Students in Cohort 2 identified all the concepts of those in Cohort 1 through discussion in small groups, which then led to a full-class sharing of small group results. Researchers observed that the level of engagement in the second cohort was higher. Students reported, as did teachers, that they were more engaged in the PBL activities. 67.6% of the students in C2 reported that they were more engaged in this unit than other units they had done that year. Only 42% reported they were more engaged in C1. Students also reported that they liked the higher engagement and open-ended questions with the scenario (29.8%) and secondly, enjoyed working in groups (26.9%) as well as dealing with a real world topic (22.1%).

All six teachers agreed in the interview that teaching science concepts matched this method well. Five of the six suggested that this be the year-long approach to their course along with teaching specific skills that matched the units. Teachers also noted that more time for planning and fewer students in the class so that they could be true facilitator/tutors would be helpful. Four of the teachers noted that students who usually received poor grades on tests did well after this unit. All six teachers reported that the test results were well within the average range for tests after more traditional units.

Although there were two clusters completing the research project and two authors of the paper regarding the study, there was only one researcher who also acted as the tutor facilitating the activities in all six classes. This research could be argued as flawed or biased because observations were not done in a systematic way due to the dual role in the classroom and because the researcher was the only one who observed all six classrooms. In addition to this, the researcher's role as tutor/facilitator of the PBL project could also influence the results. These observations, however, were then correlated with the teacher interviews and student questionnaires regarding their perceptions about PBL as an approach for secondary science. The conclusion was that the approach used with C2 was preferable based on the student and teacher feedback, but that without some background knowledge in a formal setting this might prove difficult for some topics.

Another flaw in the raw data was present in tables but it had not been put through a statistical analysis. A proper statistical analysis should be performed or a follow-up study conducted. In fact, the authors noted that conclusions from the study indicated that this approach could be used to integrate other subject areas but more research was needed. However, they did not state that this would include a statistical analysis.

Liu (2004) asked how sixth graders of different ability levels perform in a problem-based hypermedia learning environment, if there are any differences in the performance between male and female students, and what students' attitudes toward this environment and toward science learning are as a result of using this PBL environment. These questions where addressed through qualitative and quantitative methods that were combined for data triangulation.

The researchers selected two sixth grade science teachers in a middle school in a mid-sized Southwestern city to participate in the study. These teachers had 155 students their science classes. All participated in the study. Student demographics were 16% Hispanic, 6% African-American, 73% Caucasian and 5% other ethnicities. Ability level was determined b used by the district testing and nomination procedures.   73% were regular ed., 17% gifted and talented and 10% needed special support. This last group included ESL student as well as learning disabled. 73 of the students were female and 82 male. Two teachers taught these 6th graders in their science classes. Both the teachers and students were familiar with the technology used.

Researchers used a pre- and posttest of science knowledge that was designed to measure students' factual knowledge based on the concepts in the hypermedia software, *Alien Rescue*. This consisted of 25 multiple choice questions. All students took the tests. An assessment was given, measuring the students' attitude towards science. This had 14 items and was also scored on a 5-point Likert scale with 1=strongly disagree and 5=agree strongly. This assessment was given pre- and post *Alien Rescue*.

A nine-item questionnaire to examine student attitude towards *Alien Rescue* was given after its use. This looked at students' attitude toward *Alien Rescue* and their view of the educational value of it also. This was scored on a 5-point Likert scale with 1=strongly disagree and 5=agree strongly. This questionnaire was based on two used in earlier research.

Classroom observations and interviews were also done. The interviews occurred during and after *Alien Rescue* and included both students and teachers. Two researchers did the observations throughout the three-week study. Interviews and the open-ended questions were analyzed and coded for patterns and common themes by three researchers working independently of each other.

Teachers also developed a grading rubric for their students' use of the software to judge their successful placement of the aliens in new environments (the problem posed and scaffolded through the *Alien Rescue* implementation. There was more than one correct answer for the placement of each of the aliens.

There were significant differences between the three ability levels (gifted, regular education, ESL/ learning disabled when compared on the science knowledge test pre- and post the use of *Alien Rescue*. The analysis was done individually for each group as they had different knowledge starting points. The gains were largest for the regular and ESL/LD students who both doubled their scores. The gifted students did not have the same gains, but their gains were statistically significant ($p=<.05$ overall). Looking at the goal of *Alien Rescue*, (which is to find homes for the aliens) gifted students found homes for 5 aliens; regular education students found homes for 4 aliens and ESL/LD students found homes for 3 aliens. This may have been because of the amount of reading required which could skew the results towards the higher achieving students, according to the researchers.

There was no significant difference in the gains on the science knowledge test when the gender comparison was analyzed with $p<.09$. However, the posttest scores were significantly higher than the pre-test scores with $p<.01$.

There were no significant differences between the three ability levels when looking at the category of enjoyment of the *Alien Rescue* PBL $p<.17$. However, there was a significant difference in the students' view of the educational value of *Alien Rescue* with $p<.01$ with the ESL/LD students seeing less educational value than the two other groups. There were no significant differences between male and female students in their attitudes toward *Alien Rescue*. Post *Alien Rescue* scores were higher than pre- *Alien Rescue* scores on the students' attitudes toward science learning for all three groups. Female students' scores were higher than males. None reached significance.

Overall, students gained in science knowledge significantly after their unit using *Alien Rescue*. During interviews students were able to cite specific concepts that they learned and 90% indicated they found the experience very positive. Their main dislike was the 'expert' mentor built into the system and that there were no 'ready' answers. They said getting to use computers was the best part of the experience in 50% of the interviews.

Teacher interviews indicated they were pleased with the experience with many commenting on the engagement of the ESL/LD students. Interviews as well as classroom observation did not show a difference in the male and female interest or performance.

Although only two teachers participated, they were minimally involved with no direct instruction which should minimally affect the study's results. The sample size of 155 sixth grade students strengthened this study in numbers with the majority of the students in the regular education program (68%) while 17% participated in gifted and talented opportunities and 15% were receiving academic support. A weakness, however could be that Caucasian students were disproportionally represented at 72%. All the students had received instruction in how to use computers prior to the study and therefore had a knowledge base for this technology-integrated project the study was based on.

The three week length of the study was adequate since the class met every day for 45 minutes. During this time the rubric for the project on which the study was based was displayed on the board so that students knew the goals of the project.

A Likert scale was used to assess student attitudes along with a Cronbach's alpha of 0.95. Interviews during and after the study provided study information however, results based on the interviews could have been strengthened with the addition of pre-study interviews. Doctoral students were responsible for gathering the qualitative data. This is a study strength since they are versed in these research methods.

A p level of $<.01$ was given for gains in the students' scientific knowledge. However, no f value was provided for this or for the differences in knowledge levels among student groups (regular education, gifted, academic support). Not providing the f value could be considered a weakness in the study.

The researchers dismissed findings that did not reach a level of $< .05$ p. They did note when this was approached, but did not claim significance. This showed a commitment to only reaching conclusions that showed significant scientific data results and this should be considered a strength of the study.

The researchers generalized that well-designed technology tools can assist learning for middle school students of all ability levels in a PBL setting. Another conclusion was that *Alien Rescue* would be of use to other classes as a way to motivate students where attitudes towards science were not as high as in these classes. This was based on feedback from students during the interviews who recommended that the researchers share *Alien Rescue* more classes.

The study showed that PBL enhanced with a hypermedia approach can be effective with all ability levels. It can also be equally effective with both genders. Students' attitudes were positive towards the use of this software and they recommended it for other 6th grade science classes. Students' attitudes towards science were more positive after their experience than prior to it. The mixed study methods were sufficient although there was no control group.

Yew, Chong, and Schmidt (2011) asked if learning in problem-based learning is cumulative. They addressed this through a quantitative study of 218, second year science students in a Molecular Cell Biology class at a polytechnic school in Singapore from 11 randomly selected classrooms. These students were accustomed to PBL as it was the way science was taught at this polytechnic school. Teacher/facilitators also volunteered to participate in the study but were not interviewed or observed. Researchers conducted pre- and post ‘essay’ tests where the students identified concepts and key terms. From these essays the researchers developed lists of the concepts and key terms the students had identified. These tests were given 6 times, pre and post each PBL phase. Phases of PBL were research-based for identification and included: 1) Problem analysis, 2) Self-directed Learning, and 3) Reporting.

Improved test scores were significant after the three different phases ($p<.01$). After the self-directed phase and after the reporting phase the differences were significant ($p<.01$). During the collaborative problem analysis phase the differences between pre- and post essays were not significant but there was a difference between the number of concepts listed and repeated concepts $P<.05$. The researchers concluded that the learning was cumulative as the later reporting phase also had a significant number of concepts added and repeated over the pre-test when analyzing the increase in the number in the posttest. The first and last phases had more significant learning as defined by concepts cited in the posttests than did the collaborative problem analysis phase. New concepts (acquisition) were significant in both the self-directed phase and the reporting phase. The same was true for elaboration (repeated concepts).

The study's analysis was conducted through a basic testing method using single word or short-phrased concept identification rather than analysis of deeper learning. The study's applicability to long-term learning could be questioned because of the use of this methodology.

Another strength of the study was that students were already familiar with the PBL process having been exposed to this instructional model for over a year. Therefore this was a test of a stable process and delivery model.

Significant gains between pre- and posttests for student performance on scientific knowledge were reported with a $p<.01$ for the pre- and posttest. Pre- and posttest correlations were also significant with $r=.44$ and $p<.01$. This is a strength of the study.

In addition, all three phases of the project were studied to evaluate scientific knowledge growth. These were the self-directed phase, the reporting phase and the problem analysis phase. A one-way ANOVA was used to analyze the differences in learning (new concepts identified and those repeated). The results indicated that students identified different concepts during different phases. By the end of phase 1, self-directed learning, analysis showed that student concepts increased statistically for a difference from pre-project levels phase $f(2, 618.13) = 55.59$, $p<.01$, which was statistically significant and a strength of the study. The other two phases of the study reported $p<.05$ in each case which also reflects strong statistical data.

The researchers indicated that based on this study the listing of concepts and counting repeated concepts may be a valid way to quantify learning in the PBL process for large groups. This is something that is new and seen as beneficial since only small samples have been quantifiable regarding their learning in the PBL process in the past according to the researchers. The study was conducted with a large sample and validated the hypothesis to a significance of $p<.01$. It is also seen as the beginning of a way to measure learning during the PBL process, which has not been done on a large scale in the past. The researchers pointed out that the learning was confined to identifying single concepts and that students were asked to recall these after each phase. This is short-term learning rather than assessing long-term learning. It also does not assess application of the concepts except in their repetition at the reporting phase. It should be noted that there was no assessment of how the concepts linked to one another.

As shown in this section by Liu (2004), there was a statistically significant increase in scientific knowledge, particularly among regular and ESL/ learning disabled, who doubled their scores. That these techniques do not only work for the highest achieving students, but seem particularly effective for students who are most in need of effective instruction should be of significant note, particularly considering Abbott and Fouts (2002) findings that achievement is inversely correlated with income. If students who are under or average achieving are more likely to be among the lower and normal range students, then these techniques should be considered especially for lower income districts.

Liu's (2004) findings about ESL and learning disabled students success with technology based PBL is further supported by Mergendoller, Maxwell, and Bellisimo's (2006) finding that verbal ability did not play a significant role in success with PBL. As verbal ability is often an issue for ESL and learning disabled students, the fact that PBL can side step these issues effectively when employed properly is also of great importance.

These are not the only students who benefit here however, as Mergendoller, Maxwell, and Bellisimo (2006) were able to show PBL was a more effective delivery method for content than traditional instruction in general. The support offered by PBL and tech is something that all students can benefit from. Guiterrez-Perez and Pirrami's (2011) study found that the perception among students and teachers was similar; Students felt they learned better with PBL than through lectures, and teachers found PBL methods preferable to lecture methods. Perhaps most important is the long term effect that can benefit a broad base of students from diverse backgrounds. Yew, Chong, and Schmidt found that learning was cumulative in PBL, meaning that continues use on a given subject will grow student comprehension and understanding. This offers the tantalizing hope of a curriculum that benefits a large number of students from different ability levels in the long term.

PBL and Technology Scaffold Student-centered Learning

Four studies in this review demonstrate how PBL and Technology scaffold student centered learning. Park, Ertmer, and Cramer (2004) found that teachers with training in PBL technology developed more positive views of student centered learning after a year of implementation. Park and Ertmer (2007) found that preservice teachers who were instructed in technology based PBL shifted to a student centered approach to lesson plans. Callahan, Moon, and Tomlinson (1997) found that both principals and teachers have a strong belief that cooperative learning is helpful to students of all levels of capability; however most lacked sufficient understanding of cooperative learning to use it properly. Oliver and Holcomb (2008) found that when individual tablet computers were issued to students surveys showed a 20% increase in use of technology with the highest increases in math and science, Student surveys showed significant gains in computer skills, The technology director noted that the most significant noted change after the experimental year was the tablet computers' use in collaboration, and that the student survey also found a significant increase in technology supported collaborative activities.

Park, Ertmer, and Cramer (2004) studied teacher's perceptions of and pedagogical beliefs about technology-enhanced PBL, what kinds of barriers they encounter while implementing it, and what strategies are most effective in develop teacher's ability to implement technology-enhanced PBL using qualitative methods. This was done by following three teachers, starting with a two-week summer workshop on the integration of technology with PBL. Each teacher was interviews three times, before they started teaching that year, in the fall, and again in the spring. Teachers also were given journals, which they kept during the two-week training. Researchers observed the class activities and kept field notes, as well as on student presentations after the PBL units.

By the end of the study the teachers had a more positive outlook on student-centered learning from the earlier data. Teacher interviews indicated that teachers believed they had succeeded with the PBL unit but noted there were barriers. The classes were only 45 minutes long and their unit needed more time in each class period to complete the individual lessons and integrate the computer software. Another barrier was the lack of a common prep period. The teachers noted the importance of supportive administrators. The study showed that with proper training and the experience of implementation teachers will come to view the use of technology, PBL, and student centered learning positively. For the findings the study describes the methods were sufficient, though a larger sample would give the findings a better basis. Student demographics would have given the study a better context.

Callahan, Moon, and Tomlinson (1997) asked how cooperative learning is being practiced at the middle school level? This was done through a qualitative analysis of randomly sampled surveys. Proportional random samplings were used to select 1,998 middle schools to build a representative sample that included all levels of income, as well as regions of the country, and metropolitan status. The response rate was 25% and included 500 principals. Of those, 80 were sent 12 teacher surveys to be distributed to teachers across all four, core subjects. Of those teachers 449 responded. This resulted in a sample selection that is likely representative of the nation as a whole but any given area might be significantly different. Results were skewed to a single conclusion but they can probably be considered to generalize to most locations as this was a sample from across the country.

Results showed that both principals and teachers have a strong belief that cooperative learning is helpful to students of all levels of capability. However, less than 2% gave sufficient explanations of their methods to be matched with one of the primary styles of cooperative learning. Most gave detailed enough responses that it was clear they lacked sufficient understanding of cooperative learning to carry out the method they were attempting.

Strengths in this study include the use of randomly sampled surveys conducted by experienced researchers who have used these methods in the past. The survey included more than simple multiple-choice questions and each was reviewed on an individual basis. The process used proportional random samplings that accessed 1,998 middle school principals building a representative sample that included all levels of income, as well as regions of the country, and metropolitan status. However, a weakness could be that the actual sample had to be based on the response rate of 25% which in actual numbers was 500 principals. In order to keep the representative sample that still included all levels of income, as well as regions of the country, and metropolitan status, 80 principals were sent 12 teacher surveys to be distributed to teachers across all four, core subjects and of those teachers 449 responded. This represented 50% of the potential responses and is considered a high response rate. However, this sample selection that is likely representative of the nation as a whole A weakness in the study could be that results were not disaggregated for regions, income or metropolitan versus rural areas although the original surveys were sent to all categories intentionally.

Another weakness is in the survey design may have resulted in the conclusion by the researchers that based on teacher responses there is little understanding of cooperative learning. However, the researchers acknowledged that the question itself may have been poorly constructed. This was an open-ended response item.

Poor explanation may also have caused some teachers to appear to lack understanding when they in fact did, though this in and of itself would be problematic. In class observations would help establish how these techniques are being practiced in the classroom.

This survey and its findings concluded that a significant percentage of teachers do not have a full comprehension of cooperative learning and suggested that these strategies are not being implemented in a way consistent with the those which have been developed and properly researched. However, these need to be further examined in a follow-up study as noted by the researchers. Questions on the survey relating to cooperative learning need to be re-designed based on the researchers' notes regarding possible misinterpretation by teachers regarding how they described cooperative learning strategies.

Park and Ertmer (2007) asked what the differences in performance between expert and typical PBL teachers are and what are stakeholders' perceptions of the barriers teachers encounter when planning and implementing PBL in the middle school classroom and what is their relationship importance? They addressed these questions through a qualitative human performance-based model. Included were teacher and non-teacher interviews, classroom observations with checklists and researcher journals and teacher perception surveys about the barriers they found when planning and implementing PBL. The study took place in a medium-sized middle school in a small rural community in the Midwest. Twenty-one teachers were narrowed to 8 based on the short perception survey. These 8 teachers were selected to participate in the remainder of the study along with the 7 non-teachers. All participating teachers had at least one course in PBL methodology. Two university faculty (experts in PBL) and five grad assistants were then made available to help support teachers during the PBL planning and implementation portion of the study. Three of the grad assistants also collected the study's data.

Qualitative methods were used to collect data from four sources. The sources were a survey of teachers' perceptions about barriers to PBL planning and implementation, classroom observations (using checklists) by researchers to examine the gaps between expert and less than expert PBL teachers, interviews with the 8 selected teacher participants, 2 college faculty, 5 grad assistants and reflective journals by the researchers.

The differences in performance between expert and typical PBL teachers was examined by 13 hours of classroom observation in 5 classes led by the expert or typical PBL instructors. Expert teachers conducted at least 4 units in PBL and went to one training. Typical teachers went to at least one training but only taught one unit. All teachers were observed and researchers used a research-based checklist. The checklist included 6 categories: 1) Beliefs around student-centered learning, 2) Technology use for higher-order thinking, 3) Planning and organizing techniques for PBL, 4) Classroom management skills, 5) Collaboration, 6) Professional development. Teachers were also interviewed and asked about the training they had experienced relating to PBL.

Analysis of the classroom observations using the checklist and the researchers' reflective journals beyond the checklist showed a noticeable difference between the instructional practices of expert and typical PBL teachers. The biggest differences were: 1) Collaboration with other teachers, 2) Engaging students in self-evaluation and reflection on the problem-solving process and 3) Providing students with self-monitoring guidelines.

Stakeholders' perceptions of the barriers teachers encounter when planning and implementing PBL in the middle school classroom and what is their relationship importance was examined using interviews with the 8 teachers, 2 college faculty and 5 graduate assistants as well as a survey and the two researchers' reflective journals. The interview questions related to the barriers that were perceived to planning and implementing PBL units. The interviews lasted 50 minutes. Factors considered were research-based and included knowledge and skills, motivation, environment and tools, expectations, rewards, incentives and capacity. There were 8 questions where the choices were agree, disagree or unsure and one open-ended question.

Perceived barriers were identified in the following order: 1) Vision-sharing, 2) Feedback and expectations, 3) Knowledge and skills, 4) Motivation, 5) Rewards and incentives, 6) Tools and environment. Regarding vision-sharing, administrators saw the overall-purpose of PBL was to increase technology. Support faculty thought PBL was to change instructional practice and teachers were confused about the goal of PBL in the school. One teacher thought that the whole purpose was to be different from other schools. Teachers also noted that they received little feedback from administrators on how they were doing with PBL. Of the 21 teachers originally surveyed only 6 indicated they had enough training in both PBL and the accompanying technology to effective implement it. 15 of the 21 teachers were motivated to try PBL but only nine agreed there were rewards and incentives to do so. Nineteen of the 21 agreed they had the hardware to implement PBL-enhanced with technology, but in the interview sample of 8 several noted that they did have the time they would have liked to do a better job with implementation.

The researchers recommended that to maximize the use of PBL, teachers need to be able to collaborate with their peers in planning and implementation that an interdisciplinary approach enhances student engagement and that teachers should be engaging students in self-evaluation and reflection on the PBL process. They also noted that these practices are not yet part of the teaching approaches that were observed in the typical PBL teachers' classes and that may be why those teachers saw little reason to adopt this method unlike their expert PBL peers in the same school.

The study mainly focused on opinion and ideas shared among experienced PBL teachers compared to those who were less or inexperienced. That attitude among those with significant experience and training shift toward the use of collaboration among teachers and interdisciplinary curriculum is not surprising. The higher use of student self-monitoring and teacher monitoring of students is of note.

Park and Ertmer (2007) asked what the impact of problem-based learning is on preservice teachers' beliefs regarding technology use and how preservice teachers' intended teaching practices change after participation in a PBL approach to technology integration. This was addressed in a quantitative study 48 preservice teachers who had agreed to participate in the study out of the 50 in the three course sections that were asked to participate. All completed the pre- and post-surveys while only 46 completed the lesson plans, which were to be analyzed as part of the study. There were two treatment groups and one control group. All were in-tact classes, not random samples.

All groups were given a pre-course survey regarding their pedagogical beliefs about technology integration, self-efficacy beliefs (personal beliefs about one's capability in this case as they related to technology use in the classroom) and beliefs about the value of technology integration in the classroom.

Treatment groups were taught using a PBL model. To begin this they were shown two six-minute video clips, one featuring the superintendent and one the principal of a nearby school district. These two administrators shared that they had just won a five-year technology grant and that all staff and students would be given laptops the following school year. They also shared that they were looking for new teachers who would be interested in teaching in a PBL technology-integrated model. They would be examining candidate portfolios as a first step in the hiring process.

The instructor then posed the PBL question, ‘What does it take to be a successful teacher who integrates technology?’ All students were asked to turn in lesson plans during week two of the integrating technology workshop. These plans would be compared to those turned in at the end of the course.

Pre- and post- lesson plans were analyzed using a rubric to measure the changes in the students’ intended teaching practices. The graders did not know who wrote the plans nor whether they were pre- or post-course plans. There were 7 categories on the rubric: 1) teachers’ roles, 2) students’ roles, 3) curricular characteristics, 4) learning goals, 5) types of activities 6) assessment strategies 7) types of technology. Each plan was scored on a 4 point scale with 1=teacher-centered and 4=student-centered.

Throughout the remainder of the semester, students watched model teachers integrating technology digitally; part of this was classroom instruction as well as interviews with these teachers. Students watched and debriefed these videos in small groups looking for solutions to weaknesses and highlighting what the saw as strong instruction. They individually wrote reflections related to the skills, knowledge and attitudes generated by their observations and group discussions. Each group created a digital portfolio to apply for a teaching position in the district in the videos shown at the beginning of the semester. The portfolio had to demonstrate technology skills, knowledge (lesson plans were here) and an essay on their philosophy of teaching integrating technology.

The control group reviewed different multimedia programs used in K-12 classrooms and evaluated them on a form. Course content was delivered traditionally in lecture format. Two lesson plans were required using instructional software and web resources. This group also did a digital video project in groups. All three were turned in at the end of the course.

Data analysis included pre- and post- surveys containing 54 items and used to address what the impact of problem-based learning on preservice teachers' beliefs regarding technology use is. All items were rated on a 7-point scale. 1= completely disagree and 7= completely agree. Items 1-35 related to pedagogical beliefs. These were based on the Assessment of Learner-Centered Practice. The findings here were that there were no significant differences between the treatment groups. There were also no significant differences between the two treatment groups and the control group.

This question was further addressed by items 36-42, which related to teachers' self-efficacy for integrating technology. These were adapted from an earlier survey used by the researchers. The findings here were also that there were no significant differences between the treatment groups. There were also no significant differences between the two treatment groups and the control group.

Items 43-54 measured teachers' perceptions about the value of computers for instructional purposes. These came from a number of surveys used in the field. An expert in technology integration for preservice teachers reviewed these and provided suggestions that were used by the researchers in the final survey. Again the findings here were that there were no significant differences between the treatment groups. There were also no significant differences between the two treatment groups and the control group.

Researchers noted that this may have been due to no ability to randomly select students. They were already assigned to classes before the study began. The researchers also noted beliefs take time to change and the class was only a semester in length. They also noted that the survey may not have been sensitive enough to detect small changes in beliefs.

In addressing how preservice teachers' intended teaching practices change after participation in a PBL approach to technology integration there was a significant difference between the PBL groups and the control group (p=.004).The PBL groups both moved toward student-centered teaching approaches using technology while the control group's lesson plans were teacher-centered on the rubric. Four categories showed more student-centered learning approaches: 1) students' roles, p=.0016, 2) curricular characteristics, p=.0004, 3) learning goals, p=.0009, 4) types of technology p=<.0001. Overall, the researchers noted that PBL provided a hands-on opportunity to practice integration of technology into preservice teaching assignments that provided them with examples of how to do this as teachers. They also had opportunities to observe best practices in technology integration and watch interviews with these teachers and then write reflections on these video clips. They then put what they saw into practice for their own portfolios, which were presented as part of the PBL experience. These were all collaborative activities that were not part of the traditional approach the control group experienced. Also, the researchers noted that the two treatment groups had a real-life setting with the goal of competing for a teaching position in a nearby district. The control group did not have that competition as this was part of the PBL approach only.

Technology integration in post-lesson plans for PBL group included student use of search engines, software matching the PBL process, and student presentations using software such as Power Point. In the control group the technology integration remained teacher-centered, with use limited to teacher use of Power Point and projected resources only. The study was Quantitative based on surveys and rubrics. The sample was of a statistically significant number of students but the study was over a relatively short time span.

Oliver and Holcomb (2008) asked what changes are apparent in students' use and skills in technology when they are issued tablet computers, and what is the effect on classroom activities between the control group year and the experimental year. These questions were addressed in a quantitative study of 300 students spread over 60 classrooms in grades 6-8. This study was requested by the school, which is private. Classroom observations were made throughout the year. Observers used forms designed to record the use of specific technologies and activities, which were then uploaded to a survey to generate a percentage based report.

Students completed an online survey at the end of each school, which consisted of 51 open-ended and Likert-scale items. These servers were designed to collect data about student attitudes, use of, and skill levels with technology as well as classroom experiences. These surveys were analyzed using descriptive statistics and one-way between subjects Analysis of Variance when addressing the numeric responses and the difference between the control and experimental years.

During the experimental year students were issued individual tablet computers. The computers allowed assignments to be given electronically, the creation of student made wikis, OneNote software, and access to student data for teachers, and various kinds of software to be used in assignment completion. Half way through the experimental year an interview was recorded with the school technology director. This was used to provide a context to the survey and help explain the results.

The constant comparative method was used in analyzing the combined data from all sources to compare the control year to the experimental year, coding commonalities or differences across data sources, and integrating selected events as evidence for or against change in various areas of student experience such as student to student communication.

With 300 surveyed students and 60 observed classrooms, this study had a sufficient amount of both qualitative and quantitative data to generalize the findings to similar populations. Those populations, however, are limited as this was a private school that requested the study and it was limited to their population. Likert scale surveys provided a reliable tool to collect quantitative data. The observations were structured using the School Observation Method, assuring consistency to the gathered qualitative data. Findings were supported by statistically significant data with p equal to 0.05 or less, often below 0.001. Generalizations took into account any results that did not meet this criteria. Tech use increase was found at its lowest level in foreign language, with a p of 0.003 and an f of 13.42.

However, the surveys showed a 20% increase in use of technology overall, with the highest increases in math and science while other subjects, like foreign language showing smaller gains between control and experimental years. Student surveys showed significant gains in computer skills as well when the control year was compared to the experimental with the largest skill increase was the in the use of tablet computers and contributing to collaborative Wikis. In additional to students' frequent mentions of tablets in their surveys there was a large increase in mentions of the use of OneNote software as well as the use of email and Wikis for collaboration. The technology director noted that the most significant change after the experimental year was the tablet computers' use in collaboration. The student survey also found a significant increase in technology supported collaborative activities.

As discussed in this section, developing student centered learning can prove difficult. Callahan, Moon, and Tomlinson (1997) found that, even among teachers and principals who believe in the importance of student centered learning, real understanding of how to conduct student centered learning is lacking, with only 1 or 2 percent of teachers implementing recognizable techniques in their curriculum. The response to this is to consider what structures might aid in implementing student centered learning. Park, Ertmer, and Cramer (2004) found that a potential answer in their study, which showed that teachers with training in PBL technology developed more positive views of student centered learning after a year of implementation. This however shows only an increased motivation, not evidence of understanding. This can be paired with Park and Ertmer's later research in 2007, which showed that teachers who were instructed in technology based PBL sifted to a student centered approach to lesson plans. These teachers had not simply developed enthusiasm, but were implementing this curriculum.

In addition, as discussed by Callahan, Moon, and Tomlinson (1997), the use of collaboration and group work are key to student centered learning. Oliver and Holcomb (2008) found that when individual tablet computers were issued to students that the most significant noted change after the experimental year was the tablet computers' use in collaboration, and that the student survey also found a significant increase in technology supported collaborative activities. From these studies we can see that technology based

PBL not only has the power to scaffold student collaboration, but to change teacher practice and attitude. In short, technology based PBL has the power to completely transform the way students are taught.

Summary

Chapter Two addressed the ideas that motivation for learning is driven by the desire for relevance and the ability to work independently on some level. It detailed how PBL helps foster these kinds of learning opportunities and that technology adds excitement for school, as well as supporting collaboration. Chapter 2 also discussed that technology works well as a foundation for PBL as new technologies support the kind of skill set needed for long term projects. PBL in turn allows these long-term projects to become long-term learning. With technology supporting PBL the scaffolding is in place to support long term, student-centered projects by providing student centered tracking and tools of those projects. These projects are also much easier for teachers to understand and support than traditional PBL and student centered learning, as the system provides an organizational tool, which allows teachers to concentrate on facilitation rather than organization. These aspects will be further discussed below in the Classroom Implications section.

Expanding beyond the studies covered in this review, the potential for many of these practices need to be explored in a wider and more integrative way. The potential of PBL programs has been explored, but making these projects more accessible through the use of tablet computers or applying them to other subjects is the logical next step. Full quarter or even full year courses that are focused through the lens of a game like Alien Encounter warrants exploration. One can see the potential for giving students a more generalized set of goals over a given quarter and engaging students in an integrative technology supported PBL project that covers all subjects.

CHAPTER THREE: CONCLUSION

Introduction

The focus of this review was on PBL and technology working together to improve motivation through engagement and relevance through the question " What are the effects of combining technology with Problem Based Learning in a secondary classroom?" This was addressed via a discussion of how these techniques affect relevance, increasing skill and knowledge acquisition, while technology supports both teacher and student organization, making PBL more efficient and understandable across the core content areas of Language arts, social studies, mathematics and science.

Chapter One addressed the history of and reasons for Problem Based Learning and the needs and opportunities offered by the increased presence of technology in the classroom. The ideals of John Dewey (1916) were the basis for the modern movement of Problem Based Learning. The techniques which allowed the implementation of this approach were developed throughout the 20th century. Increased technological integration in the classroom allows for new opportunities to scaffold the learning experiences of students. Personal computers, the internet, laptops, and purpose designed educational software all off new and exciting ways of fostering the kinds of learning experiences John Dewey envisioned.

Chapter Two addressed the ideas that motivation for learning is driven by the desire for relevance and the ability to work independently on some level. How PBL aids in fostering learning opportunities like this is addressed as well as how technology adds excitement for school and can support collaboration. Also discussed in Chapter Two is how technology can form the foundation for PBL as technological developments support the skills needed for long term projects. The use of PBL fosters the transformation of long-term projects into long-term learning. With technology supporting PBL the scaffolding is in place to support long term, student-centered projects by providing student centered tracking and tools of those projects. Projects based on these technologies provide organizational tools allowing for much easier implementation by teachers, allowing them to concentrate on facilitation rather than organization. These aspects will be further discussed below in the Classroom Implications section.

Expanding beyond the studies covered in this review, the potential for many of these practices need to be explored in a wider and more integrative way. The potential of PBL programs has been explored, but making these projects more accessible through the use of tablet computers or applying them to other subjects is the logical next step. Full quarter or even full year courses that are focused through the lens of a game like *Alien Encounter* warrants exploration. Giving students a more generalized set of goals over the course of a given quarter and engaging students in an integrative technology supported PBL project could be done in such a way that integrated projects could cover many different subjects.

Summary of Findings

Motivation Drives Learning

Motivation drives learning. According to Blumenfeld, Hoyle, and Meece (1988), students with a greater intrinsic motivation learn to place more emphasis on goals about learning and comprehension than those with less intrinsic motivation. A similar conclusion was reached by Anderman and Gilman (2006), who maintained that students with high internal motivation are better able to function in school and had improved performance as well as perception of school. Blumenfeld, Hoyle, and Meece (1988) also noted that student goals are more aligned with real long term learning when they are motivated to learn by personal desire to engage with the content, while motivation based on external factors tends to lead to students who are status oriented yet avoid putting in effort when possible. All of the researchers noted examples of engagement that included students noting that they are being successful at tasks, reflecting on the fact that they had choices in their learning opportunities and also present themselves as confident learners.

Engagement must be kept high through those means that are available to teachers. Nystrand and Gamoran (1991) found this is best done through interacting with the content through discussion, reflective writing, extension and application of that content in a context meaningful to the student. This substantive engagement has a strong positive effect on achievement. It also includes questions focused on open-ended ideas and what students bring to the classroom (Csikszentmihalyi, Schneider, Shernoff, and Shernoff, 2003; Nystrand and Gamoran, 1999). These factors and the research of Csikszentmihalyi, Schneider, Shernoff, and Shernoff (2003) showed that to foster engagement teachers should use activities that offer choice, reflect personal goals, and offer opportunities for success, and that is effectively achieved through Problem Based Learning. Those PBL strategies and activities that align with this section's research will be discussed in later sections of this chapter.

Although all four studies used a qualitative or mixed method, they varied in their approach to examining student engagement. Thus the results also varied in their strengths and weaknesses yet all reached similar conclusions. Surveys were conducted in three of the four studies cited in this section. Anderman and Gilman (2006) limited their data collection to two surveys from ninth grade science students in the South. A key piece of data was the self-reported grade point average (GPA) from each student. Such self-reporting did align with the average GPAs at the schools, but was not confirmed by the actual grades due to privacy laws. The researchers acknowledged this as a weak point in the study.

Student surveys were also conducted by Blumenfeld, Hoyle, and Meece (1988) and Nystrand and Gamoran (1991). However, in both of these studies other data was also collected with Blumenfeld, Hoyle, and Meece adding items from the Attitudes Toward Science Survey and a science questionnaire. Weaknesses still were noted, however. The researchers shared that their data did not include actual observations of the science classrooms instead relying on the survey and questionnaire to provide classroom information, although the study included the teaching of six prescribed science lessons. Four classroom observations which focused on classroom activities were included in the Nystrand and Gamoran (1991) study and teachers, along with students were included in the survey process.

The final study in this section did not use surveys. Instead, Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) had students keep logs that they used to record their experiences. This was the only study of the four that was repeated over the course of five years at three intervals. It also used a randomized sample of high school students who had to record in their logs when a pager rang. Although this could be viewed as a strength of the study, the weakness according to the researchers was that many of the Latino and male students did not record as requested, so the data is incomplete on both these groups and results do not represent a complete picture of what engagement might mean to either male or Latino students as defined by the study.

Overall, females were overrepresented in all four studies with Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) having the most disparity (34% male to 62% female). Caucasian students were also in the majority in all of the studies with a high of 79% in the Blumenfeld, Hoyle, and Meece (1988) study, 69% in the Anderman and Gilman study (2006) followed by the 64% in the Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) study. Nystrand and Gamoran (1991) noted that their students were mainly of Northern European ethnicity but did not provide the percentage. This could be inferred as a weakness in all four studies with female data being out-weighed by male data on how engagement impacts student achievement.

The strength in the Blumenfeld, Hoyle, and Meece (1988) study was that other data besides a survey was also collected. Specifically, items from the Attitudes Toward Science Survey and a science questionnaire were added to the student survey data. These measures were used to look at science enjoyment and cognitive engagement. Nystrand and Gamoran (1991) also used multiple data points. Surveys were not only given to students but teachers as well. Classroom observations were also done four times during the project. These were analyzed to see if observations aligned with the survey results.

Several weaknesses were acknowledged by the researchers in this section. Two of these were a result of self-reporting by students. Anderman and Gilman (2006) in their quasi-experiment used as a key piece of data the self-reported grade point average (GPA) from each student. Such self-reporting did align with the average GPAs at the schools, but was not confirmed by the actual grades due to privacy laws. The researchers acknowledged this as a weak point in the study. Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) had students keep logs that they used to record their experiences.

Even through the research was done in waves over five years, according to the researchers many of the Latino and male students did not record as requested, so the data is incomplete on both these groups and results do not represent a complete picture of what engagement might mean to either male or Latino students as defined by the study.

Blumenfeld, Hoyle, and Meece (1988) shared that their data did not include actual observations of the science classrooms instead relying on the survey and questionnaire to provide classroom information, although the study included the teaching of six prescribed science lessons. Another weakness common to all the studies was the overrepresentation of females which means that data and results are incomplete for males regarding student engagement and motivation based on these four studies.

Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) used schools across the country while Anderman and Gilman (2006) conducted their work in the South. Two of the studies focused their data collection in science classes. Only one study, Nystrand and Gamoran (1991), looked exclusively at English classes and Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) collected data across the content areas. However, the results were similar to those in the other three studies. In all four studies the dominant race was Caucasian. They were in the majority in all of the studies with a high of 79% in the Blumenfeld, Hoyle, and Meece (1988) study, 69% in the Anderman and Gilman study (2006) followed by the 64% in the Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) study. Nystrand and Gamoran (1991) noted that their students were mainly of Northern European ethnicity but did not provide the percentage. Latino/Hispanic students followed with a high of 24% in the Anderman and Gilman (2006) study followed by 16% in the Csikszentmihalyi, Schneider, Shernoff, & Shernoff, (2003) project. Socio-economic status also was similar in all the studies with the middle class and lower middle class in the majority.

Examining this demographic data the trend seems to be that the research results may inform student engagement in White, middle-class America to a greater extent than the other ethnicities, races or socio-economic groups as these were not disaggregated in the results.

Problem Based Learning Increases Relevance

Problem Based Learning increases relevance, motivation and achievement. Five studies examined how motivation and achievement were improved through the use of Problem Based Learning (PBL), particularly by increasing the relevance of the instruction, which is key to student engagement, as noted in the previous section and Chapter 2. Student achievement increased when PBL methods replaced traditional teaching in the studies by Williams, Hemstreet, Liu, and Smith (1998) and Abbott and Fouts (2002). In both of these studies researchers used a state assessment to define achievement and both studies confirmed that achievement for the PBL groups increased as defined by state assessments. Abbott and Fouts (2002) used the WASL and Williams, Hemstreet, Liu, and Smith (1998) used the Texas state assessment (TAAS). In addition, the latter group also used assessments built into their curriculum software *Alien Rescue*, and found that there was a significant level of increased achievement by the PBL groups over the control group here as well.

Four of the studies noted that student engagement increased using PBL strategies. Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) found that students were more engaged and told the teachers that the learning was more relevant to them than traditional methods. Sage (1996) found that when using PBL there was a successful engagement of elementary students school students and that teachers redefined how they teach and their views on what students need to know and are able to do. This science study was designed with a community service component (school gardens), which may explain part of the successful engagement as well as the relevant context. Similarly, Williams, Hemstreet, Liu, and Smith (1998) observed that there was a personal and emotional engagement by the PBL groups regarding their 'Aliens' and the resentment they noted in interviews regarding the interference of the online mentor. Rotgans and Schmidt (2010) observed that engagement was continues regardless of group or individual activity as long as the activity was relevant to the PBL project.

Four of the studies included teacher interviews or surveys. In all four cases teachers noted the additional time needed for a PBL approach. They also identified the managing of groups as a particular challenge. However, in three of the studies researchers were focused on student data), the teachers noted that the student engagement and achievement results made it worth the effort and that they would do this again (Abbott and Fouts, 2002).

Each study had multiple measures for internal validity. Four of these studies were classroom observations (live and/or video), interviews of teachers and in some cases also interviews with parents and students. However, Williams, Hemstreet, Liu, and Smith (1998) demonstrated a strong statistical basis for results ($p<.01$) while Sage (1996) had the largest number of multiple measures. Student samples were all large with Abbott & Fouts (2002) having the largest sample of over 650 sites across Washington State. Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) triangulated their research as well. Instead of state tests, however, they observed the classroom presentations using rubrics and a classroom observation protocol. Rotgans and Schmidt (2010) used a series of surveys for their study in place of observation and found their conclusions relevant at the $p<.01$ level.

Small samples were noted in several of the studies. Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, and Kocaman (2009) had five teachers in their study. They noted that the ELL teacher had attended training in year four only. The researchers also acknowledged that the sample was small as well as limited because it was homogenous: females from the same school, who all had experience with PBL. In addition, the student sample in the control group was only 18 students compared to the 97 in the treatment group. Williams, Hemstreet, Liu, and Smith (1998) only used three classrooms and the three teachers of these classes in their study. One was the control group, one used a traditional PBL approach and the third added technology to enhance the unit. The study was an early one and the researchers intended to repeat it later. Similarly, Sage (1996) stated that the research presented was not a 'definitive piece' but an initial look at the effect of PBL use in science classes.

Designs for three of the four research projects in this section were quasi-experimental with Sage (1996) using qualitative case studies. Abbott and Fouts (2002) were the only ones who took data from an earlier study and re-analyzed it to look for the effect of PBL on high poverty schools and students. Rotgans and Schmidt (2010) used a statistical analysis of survey data in a quantitative study. The other two studies used similar designs featuring a focus on teacher practice which was measured through classroom observations and interviews.

Geographically, this set of studies included the Midwest (2), the Southwest, Washington State and Singapore. In all but one case the SES level was diverse, with Rotgans and Schmidt (2010) not listing SES information. In the case of the Abbott and Fouts (2002) study the focus was on disaggregating the high poverty schools from a larger pool of data used in a previous study. As in the prior section, females were once again in the majority overall. This included both the teachers studied (all female) and the student samples which averaged over 51% female. Teacher gender was not addressed in Rotgans and Schmidt (2010). The majority of the sites were middle schools with one elementary classroom mixed with third and fourth graders and one polytechnic school. The exception was the Abbott and Fouts (2002) study which looked at nine elementary schools plus two technical schools and nine high schools. However, all four studies used the core content areas of science, math, English/LA and history/social science for research. Science was the common subject area to all five studies.

The studies all showed that PBL as an instructional model was effective in the classrooms studied. Student achievement was raised as noted by Williams, Hemstreet, Liu, and Smith (1998) and Abbott and Fouts (2002), while student engagement was highlighted in the studies of Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins and Kocaman (2009), Williams, Hemstreet, Liu and Smith (1998), Rotgans and Schmidt (2010) and Sage (1996).

Technology Improves Motivation and Engagement

Technology improves motivation and student engagement. In this section, seven studies examined how student motivation and engagement were increased through the use of technology in the classroom. Engagement and motivation is not the exact same thing, but they are related and all seven research projects had major findings that noted the role of technology in improving student engagement. All used technology as an enhancement for curriculum delivery. In fact, the PBL model combined with technology resulted in higher motivation and engagement in every study in this section. Science was the content used in four of the studies. However, the same results were found in math (Lambic (2011) and across the curriculum in the work of Lee and Erdogan (2007) and Morgan (2008).

A variety of technology tools and software were used from the Interactive White Board Morgan (2008) to Liu's two studies that incorporated the PBL curriculum software, *Alien Rescue*. Training teachers to be comfortable with the hardware and software was also noted in all the studies. In several cases more veteran teachers indicated that they were less comfortable with technology, but found it was worth the effort because of increased student engagement and achievement this included Ertmer, Ottenbreit-Leftwich, and York (2007), Liu, Toprac, and Yuen (2009), Liu Hsieh, Cho, and Schallert (2006) and Koszalka, Grabowski, and Younghoon (2002).

The seven studies in this section had quite a few strengths. Both of the studies that Liu led confirmed the findings around motivation from earlier studies, which she also facilitated. These studies used research-based qualitative and quantitative data.

Multiple measures were used in all the studies.

The most common was the use of the student and/or teacher survey to check for positive feedback on the learning or teaching experience. Questionnaires were also used by Koszalka, Grabowski, and Younghoon (2002) as well as Lambic. These were to help confirm the survey results. Classroom observations were also employed in several studies including Morgan (2008), Lee and Erdogan (2007), Liu, Toprac, and Yuen (2009) and Koszalka, Grabowski, and Younghoon (2002). Interviews of either teachers or students were less common with only Liu, Toprac, and Yuen (2009) and Ertmer, Ottenbreit-Leftwich, and York (2007) collecting this data. Other research strengths of note included Lee and Erdogan (2007) using a randomized pool of 591 students. Liu Hsieh, Cho, and Schallert (2006) ensured multiple opportunities to randomize interview groups. This technique was used to off-set not having a control group. Additionally, Liu Hsieh, Cho, and Schallert (2006) noted that both quantitative and qualitative data showed that *Alien Rescue* was an effective tool for increasing students' scientific learning. When the two groups were compared there was a significant difference between their two posttests with the significance in favor of the *Alien Rescue* classes and $p<.001$. All studies used multiple data points were to ensure internal validity in the final analysis of results.

In both of the studies lead by Liu, there was no control group. The students were not selected randomly, but were already in self-contained science classrooms. All of the teachers used *Alien Rescue* with past classes and the software was also designed by the researchers and could have also provided a bias to the results.

Other studies also noted bias, including Morgan (2008) who conducted a single classroom study and this researcher was also teacher. Cultural bias may have interfered with the results in the Lee and Erdogan (2007) Korean culture may have interfered with PBL as students defer to adults as experts according to researchers.

The final bias that could interfere with results presented was in the Koszalka, Grabowski, and Younghoon (2002) study. The researchers were assessing a product funded by NASA and the results will inform the further development of this product for the market.

Demographics varied among the seven studies. The only one covering all grade levels was Ertmer, Ottenbreit-Leftwich, and York (2007) who investigated classrooms K-12 in the Midwest. Both the studies led by Liu took place in the Southwest and targeted middle school science students. This is because the software used in the studies was developed for this group. Morgan (2008) studied middle school students as well in an English/language arts and social studies classroom in Florida and Koszalka, Grabowski, and Younghoon (2002) focused on middle school students in rural Pennsylvania. In addition to this age group, Lambic (2011), Lee and Erdogan (2007) also included high school students with Lambic focusing on math and the other study on science. These two studies were done outside the United States. Lambic's study taking place in Serbia and Lee and Erdogan's in Korea.

Race/ethnicity and SES backgrounds of students and teachers in the studies varied. With the exception of the Lee and Erdogan (2007) in Korea, the majority race in all the studies was Caucasian followed by Hispanic and African American where races were noted. The majority of the students came from middle class backgrounds with the exception of the Koszalka, Grabowski, and Younghoon (2002) study which took place in rural Pennsylvania this same study was the only one that had a significant majority of male students (82 versus 59 females).

As reviewed in this section, including technology in the classroom has many benefits, particularly as a motivation and student engagement tool. Morgan (2008) found that even the inclusion of a single piece of technology had a significant impact; using an interactive white board improved student engagement, positive classroom behavior, and that male students' behavior and engagement improved, eliminating the gender gap in these areas. This simple inclusion is just a small example of the power of including technology in lessons, when combined with a technology based pedagogy, the effects can be far greater. Lee and Erdogan (2007) showed that motivation for learning science was greatly improved by delivering science curriculum through introducing socio-scientific issues using technology, showing that this can be an effective method for improving student success and learning. Similarly, Ertmer, Ottenbreit-Leftwich, and York's research (2007) showed that it was a belief in increased student engagement and learning that lead award winning teachers to use technology in their classrooms, showing that teachers were using these techniques for the same reasons that the previously mentioned study found to be effective.

Further, intrinsic motivation can be improved within a technology based PBL environment, Feeling competent is important to student engagement, and if this important factor can be significantly enhanced through technology, that alone is worth consideration. This is not a success which is isolated within a single discipline however, as Lambic (2011) found that teaching mathematical concepts through software and game design greatly improved motivation for learning mathematics.

Liu, Toprac, and Yuen (2009) found that a software based PBL tool was effective at engaging students in collaborative problem solving and challenged them intellectually. As collaborative problem solving is a technique that can be used in any school subject, these findings would indicate that this kind of program could be created for many different subjects.

If these techniques were especially difficult to implement or required significant setup time, these findings would be interesting, but implementing them could be considered impractical. However, Koszalka, Grabowski, and Younghoon (2002) found that teachers considered the materials flexible, used more of the resources as they became more familiar with this online approach, and that their attitude towards this approach was more positive as a result of using these resources. Clearly these are skills which teachers can develop and become engaged with, growing to see as highly valuable.

Technology Provides a Strong Basis for PBL

Technology skills provide a strong basis for PBL and technology skills are a strong foundation or partner for modern PBL teaching. This is shown in the six studies discussed in the section. Using several research designs, all six focused on instruction using problem based learning combined or embedded with technology. Professional learning opportunities prior to implementing PBL and technology were noted in Geier, Blumenthfeld, Marx et al. (2008) as well as Walker, Recker, Roberstshaw, Olsen, Leary, et al. (2011). These researchers found that first training teachers on the selected technology and then once they were comfortable with that introducing problem based instruction was most effective at assuring that the problem based learning elements would be integrated into classroom practice. Providing staff development on both technology skills along with problem based learning strategies led to technology use but not PBL. Ertmer, Ottenbreit-Leftwich, and York's research (2007) studied technology embedded into PBL, however, this team specifically chose teachers who already had technology awards for their research and then trained them in PBL strategies. Ravitz (2010) found that teachers who indicated the most use of the online features were the same teachers who felt prepared to use PBL enhanced with technology and reported less challenges.

Several studies examined technology as a way to increase student engagement in problem based learning. A key component of Problem Based Learning is critical thinking and the development of argumentation, which Belland, Glazewski, and Richardson (2010) showed can be effectively supported through hard scaffolding via a computer based tool. Similarly to Morgan (2008), Geier, Blumenthfeld, Marx et al. (2008) and Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins and Kocaman's (2009) findings show that integrating technology into PBL increases the engagement of male students without negatively impacting the engagement of female students. As motivation is such an important component to learning this further reinforces the benefits of integrating PBL and technology.

Liu, Bera, Corliss, Svinicki, and Beth (2004), Geier, Blumenthfeld, Marx et al. (2008) as well as Belland, Glazewski and Richardson (2010) found that there was a statistically significant association between cognitive tool use and cognitive processes, the more engagement the students reported the more tools they used, and that there is some empirical evidence in this study that the hypermedia-based tools assist in problem-solving learning. Belland, Glazewski, and Richardson (2010) found that hard scaffolding (technology as a support for the inquiry-based setting) enhances the students' development of argumentation in problem based learning setting.

Several studies used both multiple measures whose results paralleled each other. For example, where teachers reported using technology with a PBL approach this was confirmed by classroom observations. This was true for the quasi experimental studies of

Walker, Recker, Roberstshaw, Olsen, Leary, et al., 2011, Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) as well as Ravitz (2010) that used tracking of online use instead of classroom observation in conjunction with perception surveys regarding technology use in a PBL setting.

The largest scale study, Geier, Blumenthfeld, Marx et al. (2008) which was repeated but not replicated three times also had similar results each time regarding the positive impact of technology embedded in PBL units. This positive impact was measured, however, in student achievement on the Michigan state science assessment (MEAP) rather than in teacher perception surveys and classroom observations of PBL combined with technology use.

The same Geier, Blumenthfeld, Marx et al. (2008) study which strong results several years in a row also had several research weaknesses. Student participation was uneven with some students opting to do only one of the several science modules leading up to the MEAP and others participating for a full 1.5 years prior to the test. The only disaggregation did not allow for this but for male versus female subjects. Also, units were adjusted based on the results of the prior year's test so that curriculum also was refined annually.

In two studies, the Walker, Recker, Roberstshaw, Olsen, Leary, et al., 2011, and the Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) teachers dropped out of the study in significant numbers. Walker had a 22% loss in the first cohort and 30% in the second cohort studied. Ertmer lost one teacher, but this represented 20% as only five staff participated originally.

Three of the six studies, Geier, Blumenthfeld, Marx et al. (2008), Belland, Glazewski, and Richardson (2010) and Liu, Bera, Corliss, Svinicki, and Beth (2004), involved middle school science teachers only. Liu et. al did this because the software used was targeted at this age and content. Geier, Blumenthfeld, Marx et al. (2008) were also using an age and content specific curriculum. Belland, Glazewski, and Richardson (2010) was assessing an online 'Connection Log' that also was developed for this age and content group. Two, Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) and Walker, Recker, Roberstshaw, Olsen, Leary, et al., 2011 involved teachers from elementary, middle and high school sites and one study took place on a variety of high school campuses including small rural schools, small learning communities and large comprehensive schools to assess how technology was used by high school teachers only. Integrating PBL strategies with technology had the least effect in the large high school setting. The researcher, Ravitz (2010) noted that this setting also had the most veteran teachers and in this and other studies they were the ones who indicated a discomfort with these tools.

Race, ethnicity and SES levels were not indicated in all six studies. The ones that focused on teacher training and implementation, for example, did not reference these specifically. That included Walker, Recker, Roberstshaw, Olsen, Leary, et al., (2011), and Ravitz (2010). The Liu, Bera, Corliss, Svinicki, and Beth (2004) as well as the Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins, Kocaman (2009) provided detailed ethnic data but no SES information. Both of these studies served predominantly White, Latino and African American populations. However, their percentages varied with the former study having a 63% White, 15% Latino and 6% African American group versus the latter study almost reversing its population sample with 22% White, 66% Latino and 12% African American population. However, in both studies using technology embedded with problem based learning had a positive effect on student engagement.

Geographically, the Midwest was the setting for four of the studies, the only exceptions being the Southwest where Liu, Bera, Corliss, Svinicki, and Beth (2004) did their work and the Ravitz (2010) study, which used a broader sample across the United States.

As discussed in the studies above, technology and problem based learning work well when combined. Both effectively to motivate students and through the use of technology to support otherwise complicated or time consuming aspects of PBL. When implementing these together it is best to focus on teaching both skills simultaneously (Walker, Recker, Roberstshaw, Olsen, Leary, et al., 2011), thus allowing for a smooth integration of the two. As shown by Ravitz (2010), teachers who used online features were more prepared when it came time to engage students in tech based PBL, which shows that the more technology integrated the classroom the more efficiently a teacher can engage in these techniques.

PBL is More Effective than Traditional Methods for Skill-based Long-term Learning

Five studies found that PBL is more effective at enhancing long-term learning particularly when compared to traditional, lecture based instruction. Three of the studies were quantitative only. These researchers all noted how difficult it is to conduct quantitative research in schools because of the difficulty of providing a controlled environment. Mergendoller, Maxwell, and Bellisimo (2006) were able to do this by examining the data in a ‘Black Box’ design where they did not do any observations or interviews of students or teachers. Yew, Chong and Schmidt (2011) measured science concepts acquired by counting them in pre- and post assessments as well as counting repeated concepts. They noted that this might be the way to do quantitative research on PBL in the future. Wirkala and Kuhn (2011) noted that they had control of the classroom by providing their own instructors and not taking the students out of their environment.

All of the studies examined secondary students only and four of the five examined science topics. Only Mergendoller, Maxwell, and Bellisimo (2006) selected another content area and that was Macroeconomics.

The longest period between the PBL lessons and assessment was done by Wirkala and Kuhn (2011) who found that content was still retained by students after summer break even though the lessons ended the previous spring. In fact, both individual and group PBL experiences had this same result.

Two studies also examined the gender differences in PBL content retention and neither Liu (2004) nor Mergendoller, Maxwell, and Bellisimo (2006) found a significant difference in student learning for one gender over the other. However, both did better on the post than the pre-assessments according to the second set of researchers.

Mergendoller, Maxwell, and Bellisimo (2006) were the only researchers in this section who addressed PBL as a way to work individually. All other studies reviewed teams of students working together collaboratively. However, at least in their study by examining this individual model, they found that that verbal ability did not play a significant role in success with PBL.

One set of researchers, Guiterrez-Perez and Pirrami (2011), did not use a strictly traditional method for comparison. Both groups actually were project-based in their assignment of putting together a booklet on water conservation. However, the non-PBL group had more instruction in how to do this but the PBL group had a lecture at the end to ensure their content knowledge was there for the exams all the students had to take.

All the studies noted an increase in scientific knowledge, or in the case of Mergendoller, Maxwell, and Bellisimo (2006), macroeconomics. All teachers who were interviewed in these studies also indicated that students learned more and were more engaged in the PBL classrooms, with one exception. That was in the macroeconomics study where one classroom did better with the lecture model. However, the researchers noted that this classroom had the highest socio-economic group of students and that might have interfered with the data.

As already mentioned, the two quantitative studies had more internal validity through their ability to control their experimental environments. Student responses on surveys and questionnaires were almost 100% of the samples used (absentees were not in the final studies). All teachers in these studies did complete their initial PBL training and also completed the teaching assignments that went with the studies.

Two of the studies may have been biased by the classroom instructors as they were also part of the research team. Those studies were Wirkala and Kuhn (2011) and Guiterrez-Perez and Pirrami (2011). Additionally, two of the studies did not conduct observations in the classrooms. These two, Mergendoller, Maxwell, and Bellisimo (2006) and Yew, Chong and Schmidt (2011) relied on data collected from assessments alone.

Both were quantitative using control groups. The three others all did observations as well as assessing student learning.

Based on final assessments, concepts listed after the units ended and interviews and questionnaires given all five studies indicated the students had acquired new knowledge from the PBL model and that this model was more effective than the traditional approach. The studies took place across the country and those that provided demographics were limited. One of the quantitative studies, Mergendoller, Maxwell, and Bellisimo (2006), actually spread students evenly between classrooms so that there was an equal split of White, Hispanic and African American students in each room. No other study did this. The only other two who provided this information had a majority of White students followed by Hispanic and African American students.

Overall, the five studies found that PBL was a more effective delivery method for content and retention of that content than the more traditional models the researchers used for comparison.

PBL and Technology Scaffold Student Centered Learning

Four studies in this section demonstrate how PBL and Technology scaffold student centered learning. Park, Ertmer, and Cramer (2004) found that teachers with training in PBL technology developed more positive views of student centered learning after a year of implementation. Park and Ertmer (2007) found that preservice teachers who were instructed in technology based PBL shifted to a student centered approach to lesson plans. Callahan, Moon, and Tomlinson (1997) found that both principals and teachers have a strong belief that cooperative learning is helpful to students of all levels of capability; however most lacked sufficient understanding of cooperative learning to use it properly. Oliver and Holcomb (2008) found that when individual tablet computers were issued to students surveys showed a 20% increase in use of technology with the highest increases in math and science, Student surveys showed significant gains in computer skills, The technology director noted that the most significant change after the experimental year was the tablet computers' use in collaboration, and that the student survey also found a significant increase in technology supported collaborative activities.

Results for three of these studies indicated that after the research ended, teachers all indicated they had become much more student centered and less teacher centered in their instruction. They reported these results either in surveys, observations, questionnaires and/or interviews. This differed from the control group in the two studies that had them, Oliver and Holcomb (2008) and Park and Ertmer (2004), where the non-PBL instructors were still teacher centered.

Moving toward student centered teaching in a PBL model does have challenges as several of the studies noted. Teachers remarked on the amount of time it takes to plan both for the technology and the PBL lessons themselves. In the Park and Ertmer (2007) study 4 of the 46 pre-service teachers did not complete their plans due to lack of time. Park, Ertmer, and Cramer (2004) noted that teachers waited to do their PBL unit until six months after the training due to lack of common prep time. However, once they did the unit they indicated they would shift to the student centered classroom instruction model for fall. Part of this could have been because they were going to have a common time to plan then.

Professional learning is part of moving toward student centered PBL with technology. Park and Ertmer (2007), Park, Ertmer, and Cramer (2004) and Oliver and Holcomb

(2008) all had this in common. However, in the last case, the training was not done by the researchers but prior to their study. Callahan, Moon, and Tomlinson (1997) found that over 90% of the teachers and administrators they surveyed indicated they supported cooperative learning but over 80% failed to describe the model even when given choices which poses a question about the frequency of training needed to effectively implement a student centered approach to learning. As further discussed by Callahan, Moon, and Tomlinson (1997), the use of collaboration and group work are key to student centered learning.

Oliver and Holcomb (2008) found that when individual tablet computers were issued to students that the most significant noted change after the experimental year was the tablet computers' use in collaboration, and that the student survey also found a significant increase in technology supported collaborative activities. From these studies we can see that technology based PBL not only has the power to scaffold student collaboration, but to change teacher practice and attitude. In short, technology based PBL has the power to completely transform the way students are taught.

Classroom Implications

As most teachers have trouble properly implementing Problem Based Learning, giving them support tools is key to helping facilitate its practice. The research clearly shows that building a strong set of technology skills before training in PBL helps teachers to implement PBL more effectively. Thus it makes sense to focus on technology integration before starting PBL training. To be able to practice technology integration teachers need computers in their classrooms, and preferably enough for at least a 1:4 ratio. An alternative would be scheduling regular time in the computer labs.

A good stepping-stone to technology integrated PBL would be collaborative work with computers as an integral part of the assignments. If computer access is limited, it would be preferable to have a group gathered around a computer, with one student in charge of using the computer, while other students have clearly defined roles to keep the group on task. This will allow the teacher to work with technology integration and become comfortable with these practices. Skill with tablet computers is likely to become particularly important in this decade and should be included in professional learning.

Teachers often have trouble properly implementing collaborative learning in the classroom. This should be considered another foundational skill to be developed, ideally before the full implementation of PBL in the classroom. With these foundational skills in place teachers can be instructed in proper implementation of PBL.

Time for teachers to plan PBL projects is also important and was noted in the research. This implies a supportive administration that either provides time during the day or additional release time or pay for teachers to learn and refine their technology skills and PBL lessons. Also highlighted in the research was the need to timely technology support in the school. This is important not only for new teachers but veteran staff as well.

Administrators should be prepared for some resistance from veteran teachers who are not used to PBL, and should expect those teachers to have some trouble with implementation. The research cited earlier shows that once PBL is in place teachers find their struggles to be worth the effort, as the increase in student engagement is often felt to be worth the effort. Including training in software, which supports the teacher in implementing PBL can help ease the transition and reduce the amount of work needed on the teacher's part.

There are several smaller scale methods that become apparent from the research presented in this paper as well. In schools where there is an apparent gap between female and male student engagement the inclusion of technology can help male students to become more engaged. One option is the use of smart boards, while the inclusion of tablet computers can also be a potential source of increased engagement.

Technology integration can also be facilitated more effectively though scheduling changes in schools that have dedicated computer labs. By having the computer lab open as a potential destination for students during flex periods or home room, students can engage in collaborative projects more easily, potentially with students in other classes or subjects.

Simpler kinds of PBL to implement include having Language Arts students post journals, essays, and stories online or submit them to publishers. By making sure that students have an audience for their work they will be producing products which have a real world relevance. Arts classes should consider a similar approach, posting drawings, paintings, pictures and videos online for others to see.

Suggestions for Further Research

The studies reviewed in this paper were disproportionately focused on Caucasian students in the middle class. While other ethnic and socioeconomic groups were included, research focused on students of color and low income students would help assure that these findings can be generalized to the rest of the population. A long-term study following students over multiple years of PBL/Technology integration with an equivalent group in another school where traditional methods would be ideal for verifying the potential of long term implementation.

The studies cited in this paper show that technology based PBL can be much more effective than traditional instruction for students with lower verbal ability. For this reason Purpose designed ELL programs which are built on a PBL/Technology integration show promise and would be a good focus for a future study.

More research which focuses on the implementation of PBL in English, social studies, and math classes and exploration of effective techniques used in them, as well as how integrated classes uses PBL, such as language arts/social studies classes and science/math classes.

Observations of classrooms where collaboration is being implemented improperly and how it changes after teachers have undergone professional learning workshops seems particularly important in the light of Callahan, Moon, and Tomlinson's (1997) findings. What kinds of support are effective and how much these change teacher practices is important to understand when implementing this papers' proposals.

Conclusion

This paper focused on Problem Based Learning (PBL) combined with technology the effects of combining Problem Based Learning and technology on student engagement and motivation and how this approach may be implemented effectively. Chapter 1 discussed the history of and reasons for Problem Based Learning and the needs and opportunities offered by the rise of technological integration into the classroom. It noted the modern impetus for these developments began with the rise of constructivist thinking, based on the ideas of John Dewey, who argued for the need to give learning immediate relevance. It pointed out techniques for enabling students to engage in these kinds of learning experiences were developed throughout the 20th Century. It reviewed how new technology integrated into the classroom has provided the opportunities for students to scaffold their learning experiences and how that has increased over time.

It also pointed out how personal computers, the internet, laptops, and purpose-designed educational software all offer new and exciting ways of fostering the kinds of learning experiences John Dewey envisioned. The first chapter of this work reviewed the development of Social Constructivist education and Problem Based Learning, as well as the context in which they now exist; the era of rapid technological progress.

The need for student centered learning with real world relevance has been a frequent and controversial topic in education for over a century. With the development of Problem Based Learning in the latter half of the Twentieth Century, a codified instructional basis has been developed to deliver relevant and meaningful education to students which teaches them information and skills in a way which is highly motivating.

As technology has developed in recent decades new ways of delivering these kinds of educational experiences have become available and as this progress continues more complex and relevant learning experiences become easier to deliver.

Chapter 2 reviewed the research on how combining Problem Based Learning and technology can impact student engagement and motivation and how can this approach be implemented effectively in the classroom. This was organized into seven themes: Motivation Drives Learning, Problem Based Learning Increases Relevance, Technology Improves Motivation and Student Engagement, Technology Provides a Strong Basis for PBL, PBL is More Effective Than Traditional Methods for Skill-based Learning, and

PBL and Technology Scaffold Student-centered Learning. These themes were used to answer the guiding question: What are the effects of combining technology with Problem Based Learning in a secondary classroom?

The research reviewed in the section Motivation Drives Learning found that to foster engagement teachers should use activities that offer choice, reflect personal goals, and offer opportunities for success. The research reviewed in the section Problem Based Learning Increases Relevance, Motivation and Achievement found that PBL had a positive effect on learning and engagement and that technology is one option that lessens the amount of planning time for teachers and aids in structuring activities in which learning experiences are more accessible. The research reviewed in the section Technology Improves Motivation and Student Engagement found that including technology in the classroom has many benefits, particularly as an instructional and engagement tool. The research reviewed in the section Technology Skills Provide a Strong Basis for PBL found that the key components of PBL can be made easier for students to engage in through technology based tools. The research reviewed in the section PBL is More Effective at Enhancing Skill-based Long-term Learning than Traditional Methods of Instruction found that there was a statistically significant increase in scientific knowledge with PBL, particularly among regular and ESL/ learning disabled, who doubled their scores. The research reviewed in the section PBL and Technology Scaffold Student-centered Learning found that technology based PBL not only has the power to scaffold student collaboration, but to change teacher practice and attitude.

Chapter 3 included a summary of the findings based on the seven themes from Chapter 2, as well as implications for classroom practice and suggestions for further research. Blumenfeld, Hoyle, and Meece, J. (1988) noted that student goals are more aligned with real long term learning when they are motivated to learn by personal desire to engage with the content. Engagement must be kept high through those means which are available to teachers.

Student achievement increased when PBL methods replaced traditional teaching in the studies by Williams, Hemstreet, Liu, and Smith (1998) and Abbott and Fouts (2002). Nystrand and Gamoran in their 1991 study found this is best done through interacting with the content through discussion, reflective writing, extension and application of that content in a context meaningful to the student. This substantive engagement (as opposed to procedural engagement) has a strong positive effect on achievement. It also includes questions focused on open-ended ideas and what students bring to the classroom Csikszentmihalyi, Schneider, Shernoff, and Shernoff (2003); Nystrand and Gamoran (1991).

These factors and the research of Csikszentmihalyi, Schneider, Shernoff, and Shernoff (2003) showed that to foster engagement teachers should use activities that offer choice, reflect personal goals, and offer opportunities for success, and that it is effectively achieved through Problem Based Learning. In fact, the PBL model combined with technology resulted in higher motivation and engagement in every study in that looked at PBL and technology integration.

All forms of technology that were studied were reported to have positive effects regarding student engagement and achievement. Training teachers to be comfortable with the hardware and software first, however, was the key to effectively integrating them with PBL. Walker, Recker, Roberstshaw, Olsen, Leary, et al. (2011) found that first training teachers on the selected technology and then once they were comfortable with that introducing problem based instruction was most effective at assuring that the problem based learning elements would be integrated into classroom practice.

A key component of Problem Based Learning is critical thinking and the development of argumentation, which Belland, Glazewski, and Richardson (2010) showed can be effectively supported through hard scaffolding via a computer-based tool. Similarly to Morgan (2008), Geier, Blumenthfeld, Marx et al. (2008) and Ertmer, Glazewski, Jones, Leftwich, Goktas, Collins and Kocaman's (2009) findings show that integrating technology into PBL increases the engagement of male students without negatively impacting the engagement of female students. PBL is more effective at enhancing skill-based long-term learning than traditional methods of instruction.

Wirkala and Kuhn (2011) found that content was still retained by students after summer break even though the lessons ended the previous spring. Park, Ertmer, and Cramer (2004) found that teachers with training in PBL technology developed more positive views of student centered learning after a year of implementation. Park and Ertmer (2007) found that preservice teachers who were instructed in technology based PBL shifted to a student centered approach to lesson plans and teachers indicated either in surveys, observations, questionnaires or interviews that they had become much more student centered and less teacher centered in their instruction.

From these studies we can see that technology based PBL not only has the power to scaffold student collaboration, but to change teacher practice and attitude. In short, technology based PBL has the power to completely transform the way students are taught.

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